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FACILITY FORM 602

765-11286 (ACCESSION NUMBER)	(THRU)
106 (PAGES)	None (CODE)
(NASA CR OR TMX OR AD NUMBER)	32 (CATEGORY)

apollo

(NASA-CR-155239) STRUCTURAL ANALYSIS OF 0.105-SCALE APOLLO WIND TUNNEL MODEL (FS-2) (North American Aviation, Inc.) 106 p

N78-70078

Unclas
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SID 62-104-R-2

STRUCTURAL ANALYSIS OF THE 0.105 SCALE APOLLO WIND TUNNEL MODEL (FS-2)

(NAS9-150)

Reissued March 1963

4.5.5.1

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NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

FOREWORD

The structural analysis of the FS-2 model was performed under the NASA Apollo Contract NAS9-150.

This report was prepared by the Aero-Thermo Model Structures Group, Los Angeles Division of North American Aviation, Inc., under the direction of C. B. McClain.

ABSTRACT

This report covers the structural integrity of the Apollo FS-2 Force Model to be run in the Ames Unitary Plan Wind Tunnel and also in the North American Trisonic Wind Tunnel

Loads for the calculations shown are based on the Ames Tunnel conditions, starting or steady state, whichever gives the most critical load for the component in question. A summary sheet of Trisonic Tunnel margins of safety is included in the report also.

All components show positive margins of safety based on a safety factor of five on material ultimate; except the short (-4) tower. The tower base legs have a safety factor of 3.62 on the ultimate strength of the material with full primary and secondary stresses combined.

The balance will be overloaded in starting at $\alpha = 0^{\circ}$ unless the normal elements are used to resist side loading (roll 90°). When $\alpha = 90^{\circ}$ rolling moment will be the only overload consideration, again in starting.

All components not analyzed in this report were considered not critical.

CONTENTS

I. INTRODUCTION

This report presents a structural analysis of the 0.105-scale Apollo wind tunnel model (FS-2). Numerous configurations of the model are to be tested in the Ames Unitary Plan 8- by 7-, 9- by 7-, and 11- by 11-foot wind tunnels. The ability of the most critical of these configurations to withstand the loadings encountered during test is analyzed herein. The loadings used are based on steady-state conditions in the Ames 11- by 11-foot Unitary Plan Wind Tunnel. A summary table of margins of safety is also provided in this report to cover the load conditions these models will be subjected to in the North American Aviation, Inc., Trisonic Wind Tunnel Facility.

Test conditions are covered in this report, and starting and steady-state loading are investigated with the result that steady-state loading is critical for the model components when at a 90-degree angle of attack. The tunnel starting condition will be critical for the sting when at a 0-degree angle of attack. Starting will also be critical for the balance when at 0 and 90 degrees angle of attack.

All components to be tested in the Ames Facilities have positive margins of safety on a safety factor of 5 on material ultimate. The balance elements will be loaded above rated value unless balance installations are studied carefully.

These models are also to be tested in North American Aviation's Trisonic Wind Tunnel. The basic tower (170 inch) will have a negative margin of safety for that test unless starting angles of attack are kept below 20 degrees.

Components not analyzed in this report are concluded to be not critical.

I. INTRODUCTION

This report presents a structural analysis of the .105 Scale Apollo Wind Tunnel Model (FS-2). Numerous configurations of the model are to be tested in the Ames Unitary Plan 8 x 7, 9 x 7 and 11 x 11 foot Wind Tunnels. The ability of the most critical of these configurations to withstand the loadings encountered during test is analyzed herein. The loadings used are based on steady state conditions in the Ames 11 x 11 foot Unitary Plan Wind Tunnel.

A summary table of margins of safety is also provided herein to cover the load conditions these models will be subjected to in the North American Aviation, Inc., Trisonic Wind Tunnel Facility.

II SUMMARY

This report is a structural analysis of the most critical of various configurations of the .105 Scale Apollo Wind Tunnel Force Model (FS-2).

Test conditions covered are for the Ames Unitary Plan 8 x 7, 9 x 7, and 11 x 11 foot Wind Tunnels. Starting and steady state loading are investigated with the result that steady state loading is critical for the model components when at an angle of attack of ninety degrees. The tunnel starting condition will be critical for the sting when at zero degree angle of attack. Starting will also be critical for the balance when at zero, and also ninety degrees, angle of attack.

All components to be tested in the Ames Facilities have positive margins of safety on a safety factor of five on material ultimate. The balance elements will be loaded above rated value unless balance installations are studied carefully.

These models are also to be tested in North American Aviation's Trisonic Wind Tunnel at a later date. The basic tower (170-inch) will have a negative margin of safety for that test unless starting angles of attack are kept below twenty degrees.

Components not analyzed in this report are concluded to be not critical.

II. DISCUSSION

LAUNCH ESCAPE ROCKET MOTOR ASSEMBLY

Two escape rocket motor configurations are to be tested. One is a basic motor of cylindrical shape with a conical nose cone and a flared skirt aft; the other one is a motor with the same conical nose cone as the basic motor and a taper-sided shape (page A-3 of Appendix A). The taper is from the nose cone to the same diameter at the base (aft) as the basic motor flare skirt.

The alternate rocket motor shape is used for calculating loads on the rocket-tower-command module configurations checked in Appendix A. For critical section checks on the rocket motors, the basic motor is critical at the intersection of the cylindrical side and the skirt flare (page A-3).

Bending and compressive stresses due to normal and drag loading on the rocket are in the order of 3225 psi. When compared with a safety factor of 5 on a material ultimate of 77, 000 psi, this gives a positive margin of safety of 3. 76.

JETTISON ROCKET ASSEMBLY

As is the case with all the Apollo launch escape configurations, the jettison rocket motor is not highly loaded. It is somewhat protected by the tower structure when running at high angles of attack and is completely blocked by the rocket motor when at low angles of attack; therefore, no structural problem exists in the structure or attachment.

LAUNCH ESCAPE TOWER STRUCTURES

Four tower structures are designed for test and two are analyzed in this report. The long (240 inch) and the one equivalent to the 170-inch full-scale tower. The two short towers (120 and 80 inch) are adequate by comparison.

Leg sizes of the 240-inch and the 170-inch towers differ. The longer tower has 3/8-inch-diameter legs, and the 170-inch tower is made with 5/16-inch-diameter legs. The web members on both towers are all 1/4-inch rods.

III DISCUSSION

Launch Escape Rocket Motor Assembly

Two configurations of escape rocket motors are to be tested. One is a basic motor of cylindrical shape with a conical nose cone, and a flared skirt aft. The other one is a motor with the same conical nose cone as the basic motor and a taper sided shape, (A-3). The taper is from the nose cone to the same diameter at the base (aft) as the basic motor flare skirt.

The alternate rocket motor shape is used for calculating loads on the rocket-tower-command module configurations checked in Appendix A. For critical section checks on the rocket motors, the basic motor is critical at the intersection of the cylindrical side and the skirt flare, (A-3).

Bending and compressive stresses, due to normal and drag loading on the rocket are in the order of 3,225 psi. When compared with a safety factor of five on a material ultimate of 77,000 psi, this gives a positive margin of safety of 3.76.

Jettison Rocket Assembly

As is the case with all the Apollo launch escape configurations, the jettison rocket motor is not highly loaded. It is somewhat protected by the tower structure when running at high angle of attack and completely blocked by the rocket motor when at low angles of attack; therefore, no structural problem exists in the structure or attachment.

Launch Escape Tower Structures

Four tower structures are designed for test. Two of the four are analyzed in this report. The long (240-inch) and the one equivalent to the 170-inch full scale tower. The two short towers (120-inch and 80-inch) are adequate by comparison.

Leg sizes of the 240-inch and the 170-inch towers differ. The longer tower has three-eights inch diameter legs, and the 170-inch tower is made with five-sixteenth inch diameter legs. The web members on both towers are all one-quarter inch rods.

Construction and assembly of all members is by welding at the joints of the web members to the legs (A-4,12). All bays above the base bay are tapered panel type with one diagonal in each of four sides.

III DISCUSSION (Cont)

The base bay is a bent frame with a double beam top and two single rod knee braces in each of its four sides. Critical stresses occur at the junction of the kneebrace to the leg, and at the base of the legs where they join to the stiff rod attachment ends.

Combined compression, due to the over turning moment and side sway bending, induce stresses of 31,650 psi in the long tower and 70,000 psi in the 170-inch tower. The shorter tower is therefore most critical.

For steady state loading condition at ninety degrees angle of attack, the margin of safety for the above stress, when compared with a safety factor of 5 on material ultimate, is a negative twenty-eight percent. A true safety factor for the stresses shown is 3.62, (A-15). The long tower has a positive margin of safety of fifty-three percent for the ninety degree steady state loads, (A-9); which are the highest encountered at the Ames Facilities.

<u>Command Module</u>

Tower reactions are transferred to the command module through a pair of tower mounting blocks. These blocks attach directly to the balance block into which the balance cavities are bored. The external structure of the command module is of shell type and resists air loads only on itself. These loads are transmitted directly to the balance block.

Of significance stress wise, are the tower leg socket attachment and tower mounting block attachment to the balance block (A-17,21) and (Reference 9).

All margins of safety are one-hundred percent or more on a safety factor of five on material ultimate.

<u>Sting</u>

The sting is made in the form of a tapered, round bar, and is machined from a 17-4 PH corrosive resistant steel forging.

When the model is at zero angle of attack loads on the sting are a maximum during starting conditions. The critical section occurs at the sting to tunnel adapter socket, (A-25,28). Side and normal loads combine to cause a stress of 37,400 psi in bending. Shear stresses are in the order of 200 psi and can be neglected.

The Margin of Safety for a section at the thick part of the aft socket taper is fifty percent positive.

All members are constructed and assembled by welding at the joints of the web members to the legs (pages A-4 and A-12). All bays above the base bay are tapered panel type with one diagonal in each of four sides.

The base bay is a bent frame with a double beam top and two single rod knee braces in each of its four sides. Critical stresses occur at the junction of the kneebrace to the leg and at the base of the legs where they join to the stiff rod attachment ends.

Combined compression due to the over turning moment and side-sway bending induces stresses of 31, 650 psi in the long tower and 70, 000 psi in the 170-inch tower. The shorter tower is, therefore, most critical. For steady-state loading condition at 90 degrees angle of attack, the margin of safety for these stresses, when compared with a safety factor of 5 on material ultimate, is a negative 28 percent. A true safety factor for the stresses shown is 3.62 (page A-15). The long tower has a positive margin of safety of 53 percent for the 90-degree steady-state loads (page A-9), which are the highest encountered at the Ames Facilities.

COMMAND MODULE

Tower reactions are transferred to the command module through a pair of tower mounting blocks attached directly to the balance block into which the balance cavities are bored. The external structure of the command module is of shell type and resists air loads only on itself. These loads are transmitted directly to the balance block.

The tower leg socket attachment and tower mounting block attachment to the balance block (pages A-17 and A-21) are significant in considering stress (Reference 4).

All margins of safety are 100 percent or more on a safety factor of 5 on material ultimate.

STING

The sting is in the form of a tapered, round bar and is machined from a 17-4 PH corrosive resistant steel forging.

When the model is at 0 degrees angle of attack, loads on the sting are a maximum during starting conditions. The critical section occurs at the sting to tunnel adapter socket (pages A-25 and A-28). Side and normal loads combine to cause a stress of 37, 400 psi in bending. Shear stresses are in order of 200 psi and can be neglected.

IV MARGIN OF SAFETY TABLE

(AMES TEST)

Page	Component	Type of Stress	M.S.
A.3	-1 Rocket	Bending	3.76
A.9	-6 Tower Leg	Comp. and Bending	.53
A.10	-6 Tower Diameter	Tension	1.17
A.11	-6 Tower Welds	Shear	4.4
A.15	-4 Tower Leg	Comp. and Bending	-.28
A.18	-3 Socket Weld	Shear	1.10
A.19	-3 Socket Rod	Bending	1.97
A.19	-3 Socket Screw	Tension	3.14
A.20	-3 Socket Rod	Tension	High
A.20	-3 Socket Rod	Shear	High
A.22	-5 Block Screws	Tension	1.29
A.23	-5 Block Pins	Shear	2.64
A.30	Ames Sting	Bending	.50
A.31	Ames Balance	Side Load	-.34**
A.32	Ames Balance	Roll	-.48**

Component	TWT TEST	M.S. *	True S.F.
-1 Rocket		.79	
-6 Tower Legs		-.48	(1.56)
-6 Tower Welds		.78	
-6 Tower Diagonals		-.28	(2.15)
-4 Tower Legs	$\alpha = 50^\circ$ Start $\alpha = 20^\circ$ Start	-.77	(.714)
-3 Socket		-.47	(1.58

* Based on Safety Factor of 3 on Ult.

IV MARGIN OF SAFETY TABLE
(TWT TEST) Cont.

Balance

α =0°, TWT Start, Task 2-3/4" Bal.
-6 Tower/Alt. Rocket

Element	Rated Load	Test Load
Fwd. Normal	3750	3888
Fwd. Side	1875	4304
Chord	4200	6398

α =0°, TWT Start, Task 2-3/4" Bal.
-4 Tower/Basic Rocket & Jettison Motor at Nose

Element	Rated Load	Test Load
Fwd. Normal	Not Critical	
Fwd. Side	1877	3454
Chord	4200	6398

α =20°, TWT Start
-4 Tower/Basic Rocket with Jettison Rocket at Nose

Element	Rated Load	Test Load
** Rolling Moment	8000	5339
** Fwd. Side Force	1875	3406
Fwd. Normal	3750	4737
Chord	420	6387

** These hold for any α (a function of model angle to sting angle only, 20° used here).

The margin of safety for a section at the thick part of the aft socket taper is 50 percent positive.

MARGINS OF SAFETY

The margins of safety for the Ames tests are presented in Table 1.

Table 1. Ames Test Margins of Safety

Component	Type of Stress	Margin of Safety	Appendix Page No.
-1 Rocket	Bending	3.76	A-3
-6 Tower leg	Compression and bending	0.53	A-9
-6 Tower diameter	Tension	1.17	A-10
-6 Tower welds	Shear	4.4	A-11
-4 Tower leg	Compression and bending	-0.28	A-15
-3 Socket weld	Shear	1.10	A-18
-3 Socket rod	Bending	1.97	A-19
-3 Socket screw	Tension	3.14	A-19
-3 Socket rod	Tension	High	A-20
-3 Socket rod	Shear	High	A-20
-5 Block screws	Tension	1.29	A-22
-5 Block pins	Shear	2.64	A-23
Ames sting	Bending	0.50	A-30
Ames balance	Side load	-0.34*	A-31
Ames balance	Roll	-0.48*	A-32

*For any angle of attack and is a function of model angle to sting angle only (20 degrees used here).

V. REFERENCES

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6. "Running Loads for the 0.105 Scale Apollo FS-2 Model in Ames UPWT." NAA, Inc., Wind Tunnel Letter No. WTL 62-44, March 8, 1962.

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10. No. 7121-01079 "Assembly and Details - Launch Escape Towers (FS-2) Apollo Model" Feb. 1962, SID, NAA, Inc.

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12. No. 7121 - 01081 "Sting, Ames W.T. Apollo (FS-2) Force Model" Feb. 1962 SID, NAA, Inc.

13. No. 7121-01082 "Sting, T.W.T. FS-2 Apollo Force Model" March 1962, SID, NAA, Inc.

14. No. 7121-01083 "Installation-Ames UPWT. . . (8' x 7'), (9' x 7'), (11' x 11') Apollo (FS-2) Model", Feb. 1962, SID, NAA, Inc.

NORTH AMERICAN AVIATION, INC.

J.K.K.
JVC
3-7-62

FIGURE 1.

AMES STEADY STATE LOADS

-52-
SID 62-104
APOLLO FS-2

STEADY STATE LOADS SHEET

Model APOLLO FS-2
Tunnel UPWT 8X7, 9X7 & 11X11 FT.
Mach no. range .7 TO 3.5
Design q 450 PSF FOR α = 25° TO 95°
340 PSF FOR α = 0° TO 25°

Angle of attack range 0 TO 95° *
Angle of yaw range 0
Reference area 1.4253 FT²
Reference length 1.3475 FT
Reference span

A safety factor of 5 based on the ultimate strength or a safety factor of 3 based on the yield strength which ever is critical should be used in all design calculations.

Configuration	Attitude α	Normal lb	Side lb	Chord lb	Center of pressure spanwise	Center of pressure chordwise
COMMAND MODULE (C_2)	180°			827.5	℄	10.92" AFT OF CONE APEX
	90°	462.0		128.0	℄	
TOWER STRUCTURE (SHORT)	90°	205.5			℄	3.759" FWD OF CONE APEX
TOWER STRUCTURE (LONG)	90°	338			℄	12.162" AFT OF ROCKET SKIRT
ESCAPE ROCKET	90°	240.0		25.7	℄	8.77" AFT OF ROCKET NOSE
JETTISON MOTOR	90°	30.8			℄	3.65" AFT OF ROCKET SKIRT
LAUNCH ESCAPE SYSTEM (ET_6C_2)	90°	962.0		128.3	℄	1.05" FWD OF CONE APEX

Max. rolling moment:
Others:

REF: W.T.L. 62-44, ENCL.(1)

Approved by G. M. [illegible] JVC

* α = 180° INCLUDED FOR COMMAND MODULE MAX. CHORD FORCE

STARTING LOADS SHEET

Model 0.105 SCALE APOLLO, FS-2
Tunnel TWT
Mach no. range 0.3 TO 3.5

Angle of attack range C - 0° TO 90° LES - 0° TO 50°
Angle of yaw range 0°

Starting pressures-- Δ P (psi)

	Normal load	Side load	Chord load
Flat surfaces			
Curved surfaces	7.5	7.5	28.3

A safety factor of 3 based on the ultimate strength or a safety factor of 2 based on the yield strength whichever is critical should be used in all design calculations.

NOTE: FR. & PR. DENOTE FRONTAL & PLAN AREA RESPECTIVELY

Configuration	Attitude α	Area IN.²	Normal* lb	Side lb	Chord* lb	Center of pressure spanwise	Center of pressure chordwise
COMMAND MODULE (CR)	0°	FR. 205	989.2	989.2	5795.9	℄	4.54" fwd model base
	5°	PL. 132.8	1489.0		5690.0		
	50°		5527.9		2157.5		
	90°		3718.0		1538.0		
BASIC ESCAPE ROCET (E)	0°	FR. 19.13	404.9	404.9	517.0	℄	8.27" fwd. rocket skirt end
	5°	PL. 53.62	453		550		
	50°		1131.0		572.5		
ALTERNATE ESCAPE ROCKET (E2)	0°	FR. 19.13	498.6	498.6	517.0	℄	8.18" fwd. rocket skirt end
	5°	PL. 68.06	549.0		579.0		
	50°		1426.4		572.5		

Max. rolling moment:
Others:
* CHORD & NORMAL LOADS ARE PARALLEL AND PERPENDICULAR TO THE MODEL AXIS OF SYMMETRY RESPECTIVELY.

Approved by: [signature]

REF: WTL, 62-84, ENCL.(1)

PQ-62-20

STARTING LOADS SHEET

Model 0.105 SCALE APOLLO, FS-2
Tunnel TWT
Mach no. range 3 TO 3.5

Angle of attack range C 0° TO 90° LES 0° TO 50°
Angle of yaw range 0°

Starting pressures-- Δ P (psi)

	Normal load	Side load	Chord load
Flat surfaces			
Curved surfaces	7.5	7.5	28.3

A safety factor of 3 based on the ultimate strength or
a safety factor of 2 based on the yield strength whichever
is critical should be used in all design calculations.

NOTE: FR & PL DENOTE FRONTAL & PLAN AREAS RESPECTIVELY

Configuration	Attitude α	Area IN.²	Normal * lb	Side lb	Chord * lb	Center of pressure spanwise	Center of pressure chordwise
BASIC TOWER (T5)	0°	FR 3.31	334.0	334.0	85.3	℄	7.765" aft
	5°	PL 44.53	346.8		127.2		rocket skirt end
	50°		869.8		440.8		
ALTERNATE TOWER (T6)	0°	FR 3.31	557.6	557.6	85.3	℄	12.80" aft
	5°	PL 73.32	579.0		208.3		rocket skirt end
	50°		1550.0		795.0		
JETTISON MOTOR	0°	FR 0	43.38	43.38	0	℄	3.41" aft
	5°	PL 5.78	42.85		-3.075		rocket skirt
	50°		92.13		50.36		end

Max. rolling moment: ____________
Others:
* CHORD AND NORMAL LOADS ARE PARALLEL AND PERPENDICULAR TO THE MODEL AXIS OF SYMMETRY RESPECTIVELY.

Approved by: H. [illegible]

REF: WTL. 62-34, ENCL.(1)

STARTING LOADS SHEET

Model 0.105 SCALE APOLLO, FS-2
Tunnel AMES 11'x11' & 9'x7' UPWT
Mach no. range .7 TO 2.6

Angle of attack range 0° TO 90°
Angle of yaw range 0°

Starting pressures-- Δ P (psi)

	Normal load	Side load	Chord load
Flat surfaces			
Curved surfaces	1.215	2.08	2.08

A safety factor of 5 based on the ultimate strength or a safety factor of 9 based on the yield strength whichever is critical should be used in all design calculations.

NOTE FR & PL DENOTE FRONTAL AND PLAN AREAS RESPECTIVELY @ α = 0°

Configuration	Attitude α	Area inches²	Normal* lb	Side lb	Chord* lb	Center of pressure spanwise	Center of pressure chordwise
COMMAND MODULE (C2)	0°	FR. 205	161.20	276.00	426.00	℄	4.54" fwd.
	90°	PL. 132.8	276.00	"	249.00		model base
BASIC ESCAPE ROCKET (E)	0°	FR. 19.13	65.10	111.20	39.79	℄	8.27" fwd
	90°	PL. 53.62	111.20	"	23.22		rocket skirt end
ALTERNATE ESCAPE ROCKET (E2)	0°	FR 19.13	82.60	141.60	39.79	℄	8.18" fwd.
	90°	PL. 68.06	141.60	"	23.22		rocket skirt end
BASIC TOWER (T5)	0°	FR. 3.31	54.10	92.50	6.88	℄	7.765" aft
	90°	PL. 44.53	92.50	"	4.02		rocket skirt end
ALTERNATE TOWER (T6)	0°	FR. 3.31	89.00	152.20	6.88	℄	12.80" aft
	90°	PL. 72.32	152.20	"	4.02		rocket skirt end

Max. rolling moment: ______
Others:
* CHORD & NORMAL LOADS ARE PARALLEL AND PERPENDICULAR TO THE MODEL AXIS OF SYMMETRY RESPECTIVELY

Approved by: [signature]

REF: [illegible]

PQ-62-20

Prepared by: PLL	NORTH AMERICAN AVIATION, INC.	Page no. -5.6-
Checked by: RBR	FIGURE 3.2 AMES	Report no. SID 62-104
Date: 2-19-62	STARTING LOADS	Model no. APOLLO, FS-2

STARTING LOADS SHEET

Model 0.105 SCALE APOLLO-FS-2
Tunnel AMES 11'X11' & 9'X7' UPWT
Mach no. range .7 TO 2.6

Angle of attack range 0° TO 90°
Angle of yaw range 0°

Starting pressures-- Δ P (psi)

	Normal load	Side load	Chord load
Flat surfaces	1.215	2.08	2.08
Curved surfaces			

A safety factor of 5 based on the ultimate strength or a safety factor of 3 based on the yield strength whichever is critical should be used in all design calculations.

NOTE: FR. & PL. ARE FRONTAL & PLAN AREAS RESPECTIVELY

Configuration	Attitude α	Area inches²	Normal* lb	Side lb	Chord* lb	Center of pressure spanwise	Center of pressure chordwise
JETTISON MOTOR	0°	FR. 0	7.02	12.01	0	℄	3.41" aft
	90°	PL. 5.78	12.01	"	0		rocket skirt end

Max. rolling moment: ______
Others:
* CHORD & NORMAL LOADS ARE PARALLEL & PERPENDICULAR TO THE MODEL AXIS OF SYMMETRY RESPECTIVELY

Approved by: [signature]

REF: WTL. 62-34 EV.2(1)

PQ-62-20

NORTH AMERICAN AVIATION, INC.

PLL	FIGURE 4 TWT	-5.7-
EBR	STARTING LOADS	510 62-104
2-19-62		APOLLO, FS-2

STEADY STATE LOADS SHEET

Model 0.105 SCALE APOLLO FS-2
Tunnel TWT
Mach no. range 3 TO 3.5

Design q 2000 PSF

Angle of attack range 0° TO 50° LES; 0° TO -180° -C
Angle of yaw range 0°
Reference area 1.4261 FT²
Reference length 1.3475 FT.
Reference span 1.3475 FT.

A safety factor of ______ based on the ultimate strength or a safety factor of ______ based on the yield strength which ever is critical should be used in all design calculations.

Configuration	Attitude α	Normal lb	Side lb	Chord lb	Center of pressure spanwise	Center of pressure chordwise
COMMAND MODULE (C2)	-180°			4035.0	℄	3.89" fwd blunt end
(α = -180° BLUNT END FWD)	-145°	393.0		3340	℄	
	-90°	1371.0			℄	
LAUNCH ESCAPE SYSTEM (ET6C2)	0°	53		2771	℄	1.78" fwd blunt end
	50°	2719		1446	℄	10.07 fwd blunt end

Max. rolling moment: ______
Others:

Approved by: [signature]

REF: WTL 62-34, ENCL. (1)

PQ-62-21

STEADY STATE LOADS SHEET

Model 0.105 SCALE APOLLO FS-2
Tunnel AMES 11'x11' & 9'x7' UPWT
Mach no. range .2 TO 2.6

Design q 410 PSF

Angle of attack range 0° TO -180°
Angle of yaw range ±6°
Reference area 1.4261 FT²
Reference length 1.3475 FT.
Reference span 1.3475 FT.

A safety factor of 5 based on the ultimate strength or a safety factor of 3 based on the yield strength which ever is critical should be used in all design calculations.

Configuration	Attitude α	Normal lb	Side lb	Chord lb	Center of pressure	
					spanwise	chordwise
COMMAND MODULE (C2)	-180°			827.5	℄	3.00" from
(α=180° BLUNT END FWD)	-145°	80.6		685	℄	blunt end
	-90°	281.8			℄	
TOWER STRUCTURE	90°	289.2			℄	8.08" aft } rocket skirt end
ESCAPE [illegible]	90°	401.5			℄	8.29" fwd }
LAUNCH ESCAPE SYSTEM	0°	—		565.3	℄	9.06" fwd. blunt end
(E T&C2)	50°	541.6		301	℄	19.06 fwd blunt end
	90°	1114.3			℄	

Max. rolling moment:
Others:

Approved by [signature]

REF: WTL. 62-34, ENCL. (2)

PS-62-21

The Transonic Wind Tunnel margins of safety based on a safety factor of 3 on the ultimate are presented in Table 2.

Table 2. TWT Test Margins of Safety

Component	M.S.	True Safety Factor
-1 Rocket	0.79	
-6 Tower legs	-0.48	1.56
-6 Tower welds	0.78	
-6 Tower diagonals	-0.28	2.15
-4 Tower legs	-0.77	0.714
α = 50 deg Start		
α = 20 deg Start		
-3 Socket	-0.47	1.58

ESTIMATED TWT LOADS

The estimated loads on the -6 tower and alternate rocket configuration at 0 degrees angle of attack for TWT start using the Task 2-3/4-inch balance are as follows:

Element	Rated Load	Test Load
Forward normal	3750	3888
Forward side	1875	4304
Chord	4200	6398

The estimated loads on the -4 tower with the basic rocket and jettison motor at the nose at 0 degrees angle of attack for TWT start using the Task 2-3/4-inch balance are as follows:

Element	Rated Load	Test Load
Forward normal	Not critical	
Forward side	1877	3454
Chord	4200	6398

The estimated loads on the -4 tower with the basic rocket with the jettison rocket at the nose at 20 degrees angle of attack for TWT start are as follows:

Element	Rated Load	Test Load
*Rolling moment	8000	5339
*Forward side force	1875	3406
Forward normal	3750	4737
Chord	420	6387

*For any angle of attack and is a function of model angle to sting angle only.

III. REFERENCES

1. Assembly and Details - Command Module FS-2 Apollo Force Model. NAA S&ID, Drawing No. 7121-01077 (February 1962).

2. Assembly and Details - Launch Escape Towers FS-2 Apollo Model. NAA S&ID, Drawing No. 7121-01079 (February 1962).

3. Assembly and Details - Rocket Motors, Apollo FS-2 Model. NAA S&ID, Drawing No. 7121-01080 (February 1962).

4. Details - Balance Block and Miscellaneous, 0.105-Scale FS-2 Apollo. NAA S&ID, Drawing No. 7121-01078 (February 1962).

5. Installation - Ames UPWT (8-by 7-foot, 9-by 7-foot, and 11-by 11-foot) Apollo FS-2 Model. NAA S&ID, Drawing No. 7121-01083 (February 1962).

6. Model Assembly - Apollo FS-2 Force Model. NAA S&ID, Drawing No. 7121-01076 (March 1962).

7. Model Design Structures Manual. NAA LAD, NA52-332 (Revised 1962).

8. Roark, R. J. Formulas for Stress and Strain, 3rd edition. New York: McGraw-Hill Book Company, Inc., 1954.

9. Running Loads for the 0.105-Scale Apollo FS-2 Model in Ames UPWT. NAA Wind Tunnel Letter No. WTL 62-44 (18 March 1962).

10. Starting and Running Loads for the 0.105-Scale Apollo FS-2 Model. NAA Wind Tunnel Letter No. WTL 62-34 (19 February 1962).

11. Sting, Ames Wind Tunnel Apollo FS-2 Force Model. NAA S&ID, Drawing No. 7121-01081 (February 1962).

12. Sting, TWT FS-2 Apollo Force Model. NAA S&ID, Drawing No. 7121-01082 (March 1962).

13. Strength of Metal Aircraft Elements. U.S. Department of Defense, MIL-HDBK-5 Armed Forces Supply Support Center, Washington, D.C. (1961).

14. Structure Manual, Vol. I and II. NAA LAD NA52-400 (Revised 1962).

APPENDIX A

STRUCTURAL ANALYSIS

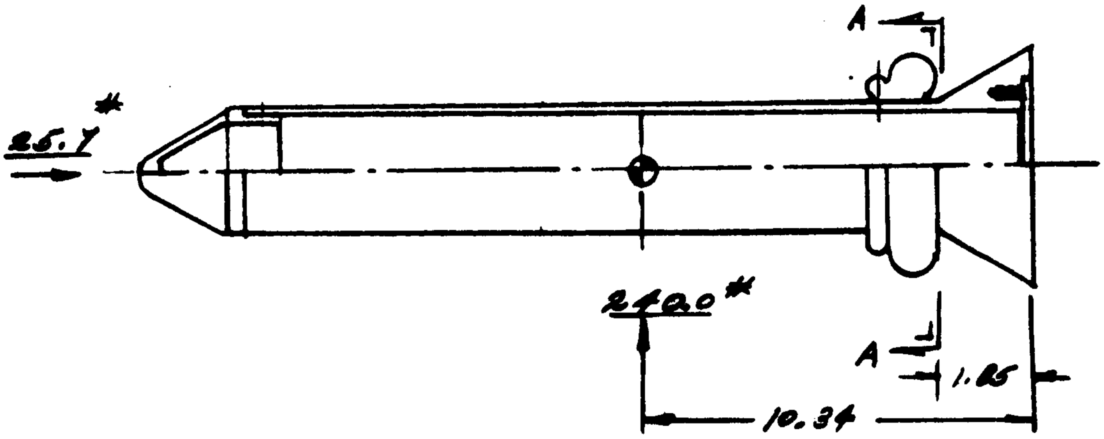
APPENDIX A

Contents

7121-01080

-1 ROCKET MOTOR ASSY ; MAT'L 7075 T6 ALUM.

(BASIC ROCKET MOTOR)

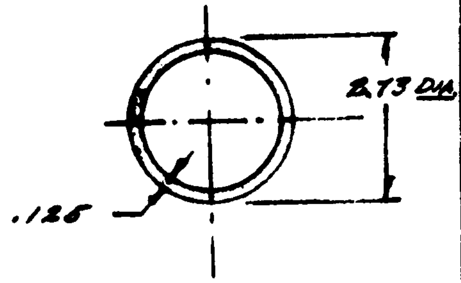


BENDING SECTION A-A:

$Z = .09817(d^4 - d_1^4)/d$

$= .09817(2.73^4 - 2.48^4)/2.73$

$= \underline{.6372}\ ''^3$



SECT. A-A

$A = \underline{1.023}\ ''^2$

$M = 240(10.34 - 1.85)$

$= (240.0)(8.49)$

$= \underline{2037.6}\ ''\#$

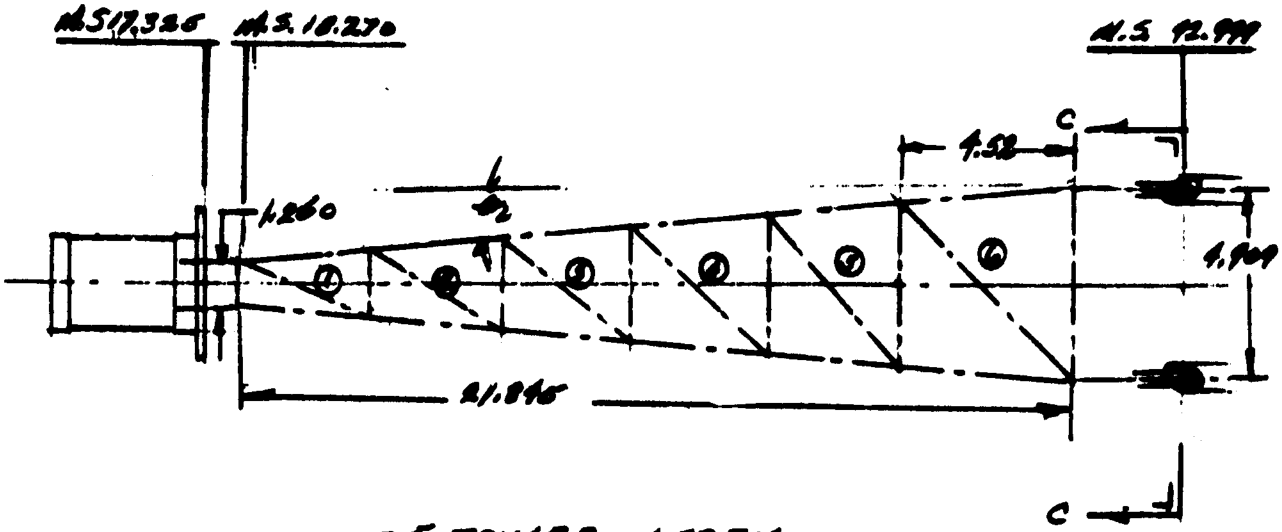
$f_b = \frac{M}{Z} + P/A = 2038/.637 + 25.7/1.023$

$= 3,200 + 25. = \underline{3,225}\ \#/''^2$

$M.S. = \frac{77}{(5)3.23} - 1 = \underline{\underline{3.76}}$

7121-01079

LONG TOWER (-6) / ALTERNATE ROCKET



-5 TOWER ASSEM.

MAT'L. - 17-4PH CRES
H.T- 190-210KSI

SPACE GEOMETRY -

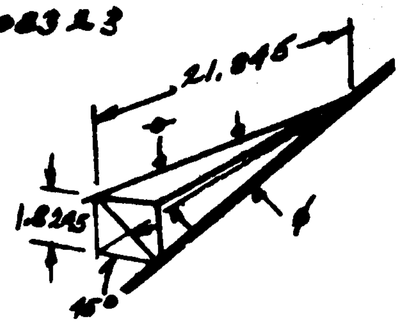
$\theta_L = TAN^{-1}(4.909-1.260)/2(21.846) = TAN^{-1}.08352$
$= 4°46'+$

$\cos\theta_L = .99653$; $\sin\theta_L = .08323$

$\phi_L = TAN^{-1}(1.8245)(1.414)/21.846$

$= TAN^{-1}.11809$

$= 6°44'+$



$\cos\phi_L = .99310$; $\sin\phi_L = .11728$

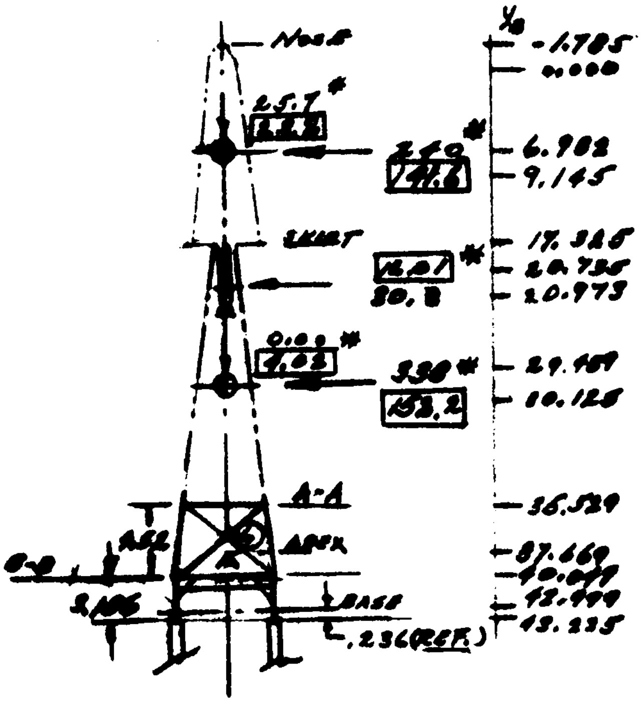
MAIN TAPER COL. LOAD FACTOR

$= 1/.99310 = \underline{1.007}$

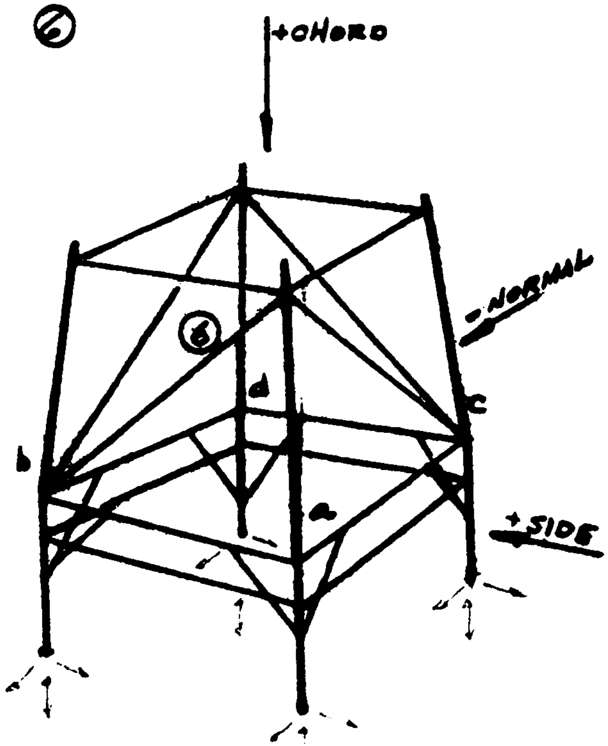
7121-01077

-6 TOWER - LONG - (CONT.)

MEMBER LOADS BAY ⑥



LOADS DIAGRAM. (AMES)



TOWER BASE & BAY ⑥

CRITICAL LOADING CONDITION STUDY - (AMES)

STEADY STATE, (NON-BOXED VALUES (NORMAL ONLY))

$$\Sigma M_{N_{BB}} = 240(40.099-6.982) + 338(40.099-29.489) + 30.8(40.099-20.973)$$

$$= 7936.1 + 3568.5 + 587.5 = \underline{12{,}093}\ ^{\text{"}\#}$$

$$\Sigma M_{N_{AA}} = 12093 - 608.8(4.52) = \underline{9341}\ ^{\text{"}\#}$$

$$\Sigma M_{S_{BB}} = \Sigma M_{S_{AA}} = 0.0$$

$$\Sigma P_N = 240 + 338 + 30.8 = \underline{608.8}\ ^{\#}$$

$$\Sigma P_C = \underline{25.7}\ ^{\#}$$

7121-01079

-6 TOWER - LONG - (CONT.)

MEMBER LOADS BAY ⑥ (CONT.)

STARTING - (BOXED VALUES - (SAME NORMAL & SIDE)

$$\Sigma M_{SB\text{-}B} = \Sigma M_{NBB} = 191.6(40.019-9.145)$$
$$+\ 12.01(40.019-20.735)+152.2(40.019-30.125)$$
$$= 4{,}376.0 + 232.0 + 1{,}510.4 = \boxed{6118.4}\ ^{\#}$$

$$\Sigma M_{SA\text{-}A} = \Sigma M_{N\text{-}AA} = 6118.4 - 305.8(4.52) = \boxed{4736.2}\ ^{\#}$$

$$\Sigma P_N = \Sigma P_S = \boxed{305.8}\ ^{*}$$

$$\Sigma P_C = \boxed{27.24}\ ^{*}$$

CRITICAL MEMBER LOADS -

$$P_{d_N} = -P_{a_N} = {}^{+}1.007\left\{\begin{matrix}12{,}093.7\\ \boxed{6118.4}\end{matrix}\right\} / 2(4.909) = \begin{matrix}1240.3^{\#}\\ \boxed{627.5}\end{matrix}$$

$$P_{c_N} = -P_{b_N} = 1.007\left\{\begin{matrix}9{,}341\\ \boxed{4736.2}\end{matrix}\right\} / 2(4.312) = \begin{matrix}1090.7\\ \boxed{553.0}\end{matrix}$$

$$P_{a_S} = -P_{d_S} = 1.007\left\{\begin{matrix}-\\ \boxed{6118.4}\end{matrix}\right\} / 9.818 = \begin{matrix}-\\ \boxed{627.5}\end{matrix}$$

$$P_{c_S} = -P_{b_S} = 1.007\left\{\begin{matrix}-\\ \boxed{4736.2}\end{matrix}\right\} / 8.624 = \begin{matrix}-\\ \boxed{553.0}\end{matrix}$$

$$P_d = -P_a = P_{a_N} \pm P_{a_S} = \left\{\begin{matrix}1240.3 \pm 0 = \pm 1240.3\\ 627.5 \pm 627.5 = \boxed{\pm 1255.0 / 0.0}\end{matrix}\right.$$

$$P_b = -P_c = P_{c_N} \pm P_{c_S} = \left\{\begin{matrix}\mp 1090.7 \pm 0 = \pm 1090.7\\ 553.0 \pm 553.0 = \boxed{\pm 1106.0 / 0.0}\end{matrix}\right.$$

* REF. PG. A.4

7121-01079

= 6 TOWER - LONG - (CONT.)

MEMBER LOADS BAY 6 (CONT.)

(+ TENSION, - COMP.)

$$P_a = \begin{cases} +1240.3 - 6.43 = +1233.9^{*} \\ +\boxed{1255.0} - \boxed{6.86} = \boxed{+1248.1} \end{cases} \quad 1.1\%\Delta$$

$$P_b = \begin{cases} +1090.7 - 6.43 = +1084.3^{*} \\ - \quad - \boxed{6.86} = \boxed{-6.86} \end{cases}$$

$$P_c = \begin{cases} -1090.7 - 6.43 = -1097.1^{*} \\ - \quad - \boxed{6.86} = \boxed{-6.86} \end{cases}$$

$$P_d = \begin{cases} -1240.2 - 6.43 = -1246.7^{*} \\ - \boxed{1255.0} - \boxed{6.86} = \boxed{-1261.9} \end{cases} \quad 1.3\%\Delta$$

$$P_{a_c} = P_{b_c} = P_{c_c} = P_{d_c} = .1007 \begin{Bmatrix} 25.7 \\ 27.4 \end{Bmatrix} / 4 = \begin{matrix} -6.43 \\ \boxed{-6.86} \end{matrix}$$

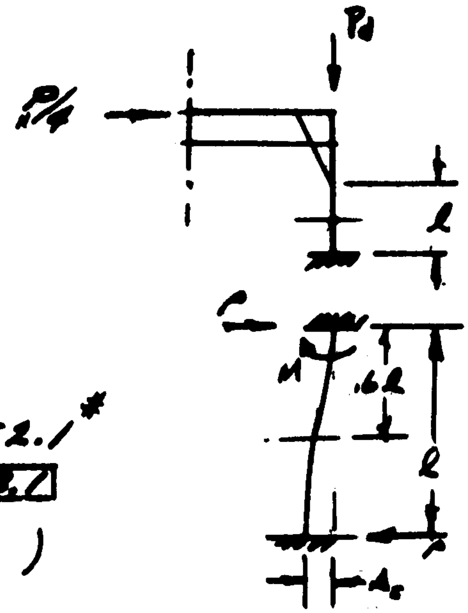
PRIMARY LOAD STRESS ARE THE SAME FOR START AND STEADY STATE, BUT THE SECONDARY BENDING STRESSES FOR THE STEADY STATE COND. ARE HIGHER THAN THOSE FOR STARTING. THEREFORE THE STEADY STATE LOADS WILL BE USED FOR ANALYSIS

7121 - 01079

-6 TOWER - LONG - (CONT)

SECONDARY BENDING MOMENTS.

ASSUMING INFLECTION POINT AT 60% OF ℓ AND BOTH ENDS FIXED.



$M_{CR} = P(.6\ell)$

$P = \begin{cases} 608.8/4 = 152.1^{\#} \\ \boxed{305.4}(1.414)/4 = \boxed{108.1} \end{cases}$

(REF. PG. A5 & 6)

$\ell = (43.325 - 40.049 - 2.120) = \underline{1.156}''$

(REF: 9. & PG. A.5)

$M_{CR} = 152.1(.6)(1.156) = \underline{105.5}''^{\#}$

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-6 TOWER-LONG-(CONT.)

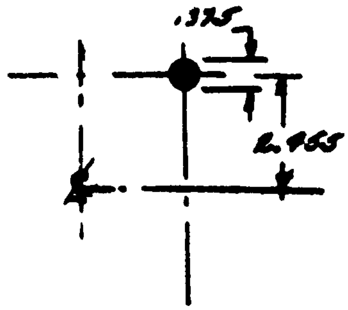
PRIMARY COMP. STRESS (MAX)

$$f_c = \frac{P}{A} = 1246.7/.1105$$

$$= \underline{11,282.3} \text{ \#/in}^2$$

$$F_c = 190,000 \text{ PSI}$$

$$R_c = \frac{5(11282.3)}{190,000} = \underline{.297}$$



$A_o = \underline{.1106} \text{ in}^2$

$I_o = \underline{.000971} \text{ in}^4$

SECONDARY BENDING STRESS

$$f_b = \frac{Mc}{I} = 105.5(.1875)/.000971$$

$$= \underline{20,371} \text{ \#/in}^2$$

$$F_b = 280,000 \text{ PSI}$$

$$R_b = \frac{5(20,371)}{280,000} = \underline{.364}$$

$$M.S. = \frac{1}{R_c + R_b} - 1 = \frac{1}{.297 + .364} - 1 = \underline{.53}$$

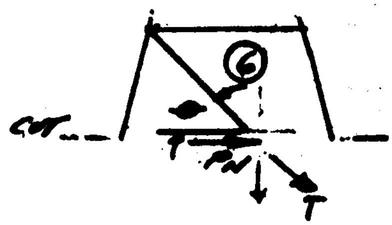
7121-01079

- 6. TOWER - LONG. - (CONT.)

BAY 6 DIAGONAL MEMBERS (SHEAR)

MAX. LOAD ASSUMED ON ONE MEMBER IN TENSION -

P_N = 608.8# (REF. Pg A.6) (CONSERVATIVE)



$\theta \cong 45°$, $\cos\theta = .7071$

$T = 608.8/.7071$

$= 861$#

$f_t = \frac{T}{A} = \frac{861}{.0491}$

$= 17,536$ #/IN²

MEM. SECT.
$A = .0491$ IN²

$F_t = 190,000$ PSI

$M.S. = \frac{190}{5(17.5)} - 1 = 1.17$

PREPARED BY: CKM	NORTH AMERICAN AVIATION, INC.	PAGE NO. -A.11- OF
CHECKED BY: CCLI	.105 SCALE FS-2 APOLLO	SID-62-104 REPORT NO.
DATE 2.16.62	FORCE MODEL	MODEL NO.

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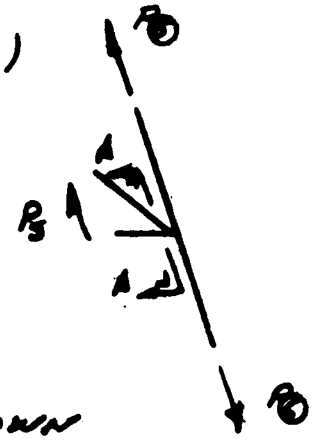
-5 TOWER ASSEM. (CONT.)

WELDED JOINTS -

$P_{⑥} = 1240.3^{\#}$ (REF. PG. A.6)

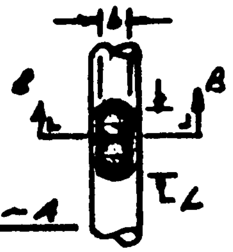
$P_{⑤} = 1090.7^{\#}$



$P_S = P_6 - P_5 = 1240.3 - 1090.7$

$= \underline{149.6}^{\#}$

ASSUME $A_{S_{ME}}$ = SHADED AREA SHOWN IN SECTION A-A



A-A

$b = d = .25"$

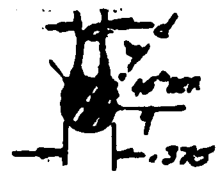
$L = 2(.25 + .062) = .624"$

$A_S = b(d) - .7854(d)^2$

$+ .062(3/8)\pi(d)$

$= (.25)^2 - .7854(.25)^2 + .0413(3.14)(.25)$

$= .0134 + .0324 = \underline{.0458}$ $\square"$



B-B

.375(.707)
=.361

$f_S = P/A = 149.6/.0458(.707) = \underline{4615}$ #/IN2

$F_S = 125,000$ PSI (REF. 1.).

$M.S. = \dfrac{125}{(5)4.6} - 1 = \underline{4.4}$

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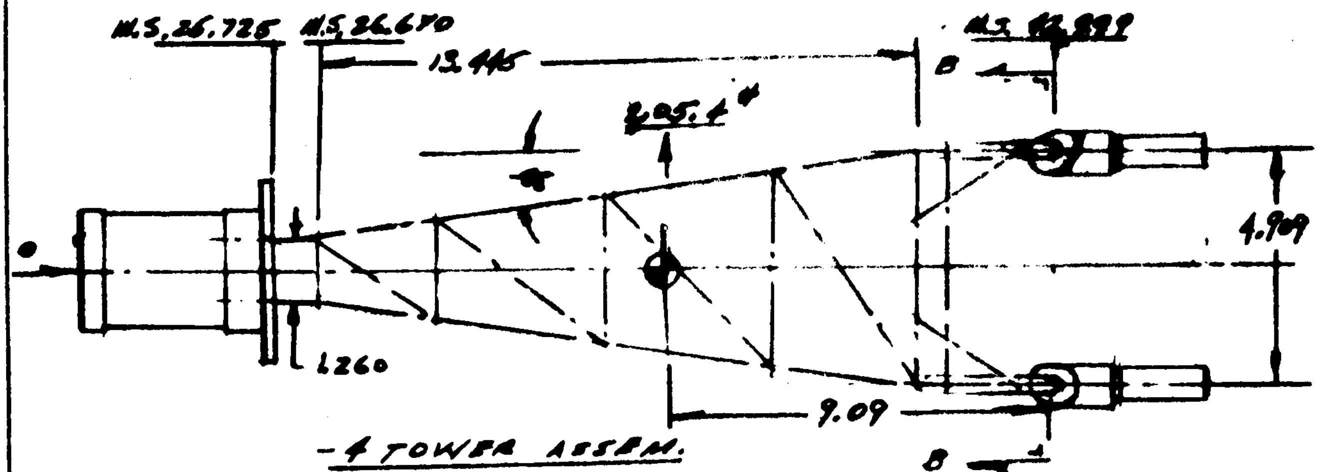
-4 TOWER ASSY.- ; MAT'L - 17-4PH, H.T. 180KSI.

(SHORT TOWER / ALTERNATE ROCKET)



SPACE GEOMETRY:-

$\theta_s = TAN^{-1}(4.909 - 1.260)/(2 \times 13.445) = TAN^{-1} .13570$

$= 7° 44'+$

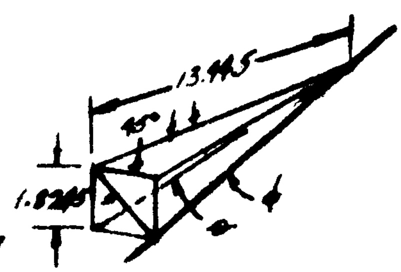
$COS\ \theta = .99091$; $SIN\ \theta = .13446$

$\phi = TAN^{-1}(1.8245)(1.414)/13.445$

$= TAN^{-1} .19188$

$= 10° 51'+$

$COS\ \phi = .98209$; $SIN\ \phi = .18843$



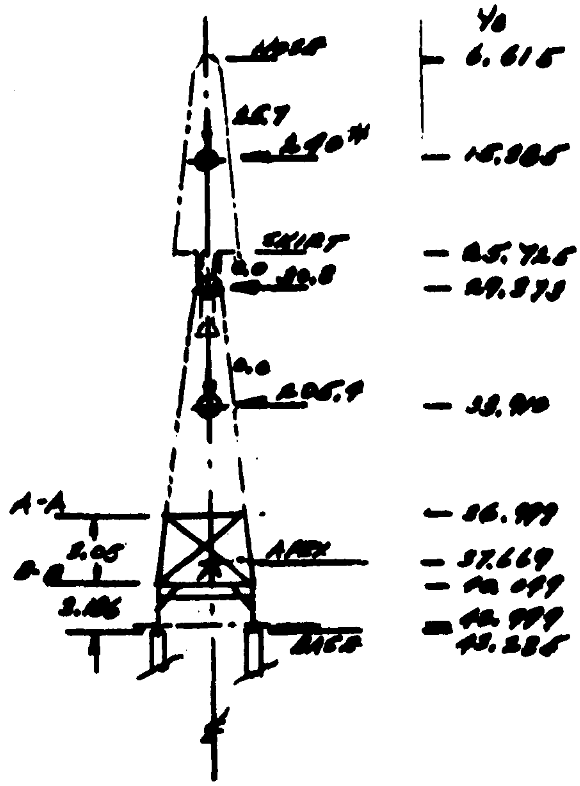
MAIN TAPER COL. LOAD FACTOR

$= 1/.98209 = \underline{1.018}$

7121-01079

- 4. TOWER - SHORT - (CONT.)

THE STEADY STATE LOADING CONDITION WAS CRITICAL FOR THE LONG TOWER, AND THEREFORE WILL BE USED FOR THE SHORT ONE.



LOAD GEOMETRY. (AMES)

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-4 TOWER - SHORT - (CONT.)

$\Sigma M_{N_{BB}} = 240(40.049-15.385) + 30.8(40.049-29.373)$
$+ 205.4(40.049-33.910)$
$= 5919.3 + 328.8 + 1260.9 = \underline{7509.0}$ in#

$\Sigma M_{N_{A-A}} = 7509 - 476.2(3.05) = \underline{6055.7}$ in#

$\Sigma M_{S_{BB}} = \Sigma M_{S_{AA}} = 0.0$

$\Sigma P_N = 240 + 30.8 + 205.4 = \underline{476.2}$#

$\Sigma P_c = \underline{25.7}$#

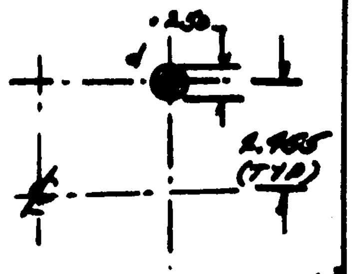
$P_{dN} = -P_{aN} = 1.018(7509.0)/2(4.909) = \pm \underline{778.6}$#

$P_{cN} = -P_{bN} = 1.018(6055.7)/2(4.318) = \pm \underline{714.8}$#

$P_S = 0.0$

PRIMARY COMP. STRESS

$P_a = P_{dN} + P_c/4 = 778.6 + 25.7/4$
$= 778.6 + 6.4 = \underline{785.0}$#



$f_c = P/A = 785/.0491 = \underline{15,988}$ #/in²

$F_c = \underline{190,000 \text{ PSI}}$

$A_c = \underline{.0491}$ in²

$R_c = \frac{5(15.99)}{190.0} = \underline{.421}$

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℄ TOWER - SHORT - (CONT.)

SECONDARY BENDING STRESS -

$M_{CR} = P(.6\ell)$ (REF. PG. A.8)

$P = 476.2/4 = \underline{119}$ #

$\ell = 1.156$' (REF. PG. A.8)

$M_{CR} = 119(.6)(1.156) = \underline{82.5}$ "#

$I = (.25)^4(.0491) = \underline{.000192}$ "^{4}

$f_b = \frac{Mc}{I} = \frac{82.5(.125)}{.000192} = \underline{53,711}$ #/in²

$F_b = 280$ KSI.

$R_b = \frac{5(53.7)}{280.0} = \underline{.959}$

$M.S. = \frac{1}{R_c + R_b} - 1 = \frac{1}{.121 + .959} - 1 = \underline{-.20}$

$S.F_{(TRUE)}$ ON ULT. = $\underline{3.62}$

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-4 TOWER - SHORT - (CONT.)

THE DIAGONAL MEMBERS AND WELDS ARE NOT CRITICAL BY COMPARISON WITH THE LONG TOWER.

COLUMN CHECK OF MAIN TAPER MEMBER (d).

$L = 1.018(3.05) = \underline{3.105}"$

$P = 778.6 + 6.4(1.018) = \underline{785.1}^{\#}$

$$P_{CR} = \frac{n\pi^2 EI}{L^2}$$

$n = 2$ (PARTIAL FIXITY ASSUMED)

$E = 28.5 \times 10^6$ PSI

$I = .000192$ (REF. PG. A.15)

$$P_{CR} = \frac{2(3.14)^2(28.5)(.000192)\times 10^6}{(3.105)^2} = \underline{11,203}^{\#}$$

NOT CRITICAL

7121-01079

-3 SOCKET

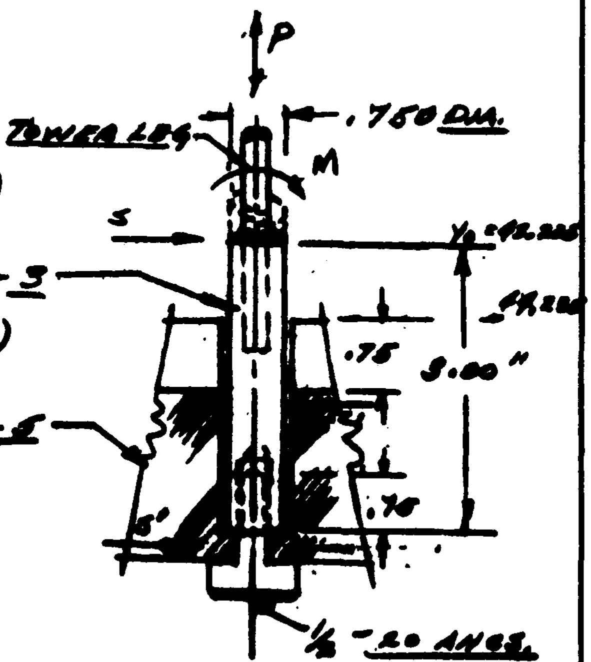
MAX. LOAD & MOM. OCCUR WITH LONG TOWER

P_c = 1246.7 # } (REF. PG. A.7)

P_t = 1233.9 #

S = 152.1 # } (REF. PG. A.8)

M = 105.5 "#



WELD CHECK -

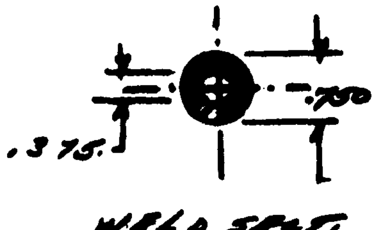
ASSUME WELD IS FILLET.

$t_s = [(.750 - .375)/2](.707)$

$= .1326$ "

$r_{(EFF)} = (.375 - .1875)(.25) + .1875$

$= .2344$ "



$A_s = 2\pi r t = 2(3.14)(.2344)(.1326)$

$= .1953$ "^{2}

$I_o \cong \pi r^3 t = 3.14(.2344)^3(.1326)$

$= .00536$ "^{4}

$c = .1875(1.5) = .2812$ "

7121-01079

-3 SOCKET (CONT.)

$$f_s = P/A + \frac{Mc}{I} = \frac{1233.9}{.1953} + \frac{105.5(.2818)}{.00536}$$

$$= 6320 + 5535^{*} = \underline{11,855} \ {}^{\#}/_{IN^2}$$

*(CONSERVATIVE AS SOCKET HOLE WILL TAKE MOM.)

$F_s = 125,000$ PSI

$$M.S. = \frac{125}{.5(11.86)} - 1 = \underline{1.10}$$

-3 SOCKET ROD BENDING -

ASSUME BASE OF LEG HOLE & EDGE OF -5 BLOCK COINCIDE -

$P = \underline{1296.7}^{\#}$

$M = 152.1(44.385 - 42.335 + .75) + 105.5$

$= 266.2 + 105.5 = \underline{371.7}$ "#

$A_t = (.75^2 - .375^2)(.7854) = \underline{.3600}$ "^{2}

$I_o = (.75^4 - .375^4)(.0491) = \underline{.0150}$ "^{4}

$c = \underline{.375}$ "

7121-01079

-3 SOCKET (CONT)

ROD BENDING (CONT)

$$f_b = \frac{P}{A} + \frac{Mc}{I} = \frac{1246.7}{.3600} + \frac{371.7(.375)}{.0150}$$

$$= 3,463 + 9293 = \underline{12,755}\ ^{\#}/_{IN^2}$$

$$F_b = \underline{190,000}\ (\text{CONSER})$$

$$M.S. = \frac{190.}{12.76(5)} - 1 = \underline{\underline{1.97}}$$

$\frac{1}{2}$-20 AHCS.

$$P_t = \underline{25,550}$$

$$P_t = \underline{1233.9^{\#}}$$

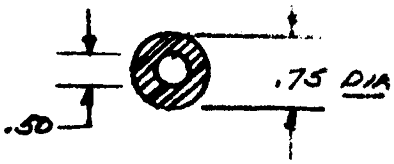
$$M.S. = \frac{25,550}{1,233.9(5)} - 1 = \underline{3.14}$$

7121-01079

TOWER ATTACHMENTS (-3 SOCKET)

1/2-20 AHCS - (CONT.)

LEG NET AREA IN
TENSION & BEARING -



$P = 1233.9^{\#}$ (-5 TOWER)

$A_s = (.75^2 - .50^2).7854 = .2454 \ in^2$

$f_s = P/A = 1233.9/.2454 = \underline{5028} \ \#/in^2$

$F_s = \underline{190,000}$ PSI

$M.S. = \frac{190}{5(5.03)} - 1 = \underline{\underline{HIGH}}$

1/2-20 AHCS THD. SHEAR -

(REF. 1.)

$A_s = .7324(\ell)$

$\ell = .75$ $\cdot$(75% OF TAPPED LENGTH)

$A_s = .7324(.75) = \underline{.5493} \ in^2$

$f_s = P/A = 1233.9/.5493 = 2245 \ \#/in^2$

$F_s = 95$ KSI.

$M.S. = \underline{\underline{HIGH}}$

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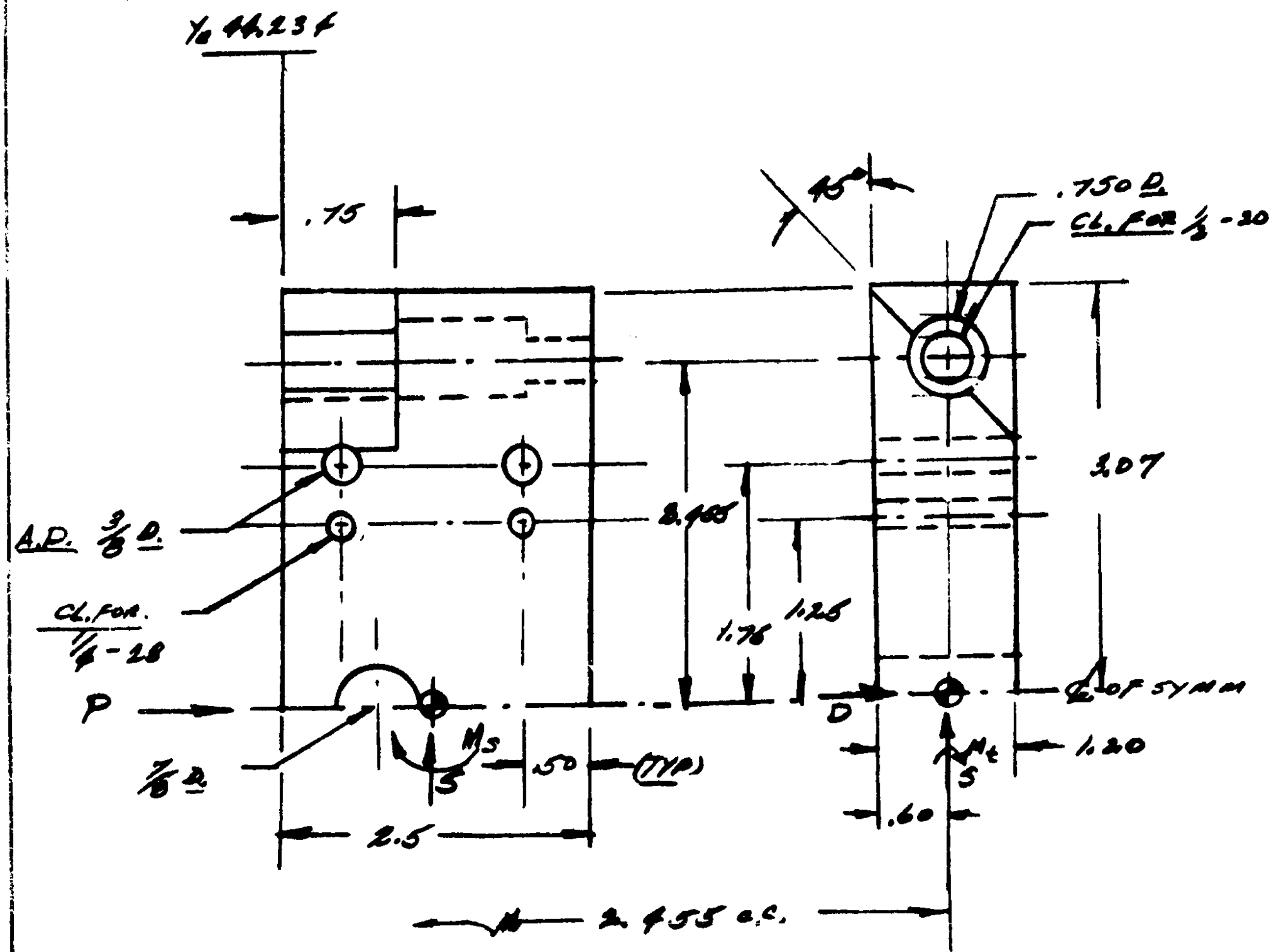
7121-01078

-5 TOWER MOUNT BLOCK -



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DATE: 3-6-62	FORCE MODEL	MODEL NO.

7121-01078

-5 TOWER MOUNT BLOCK-

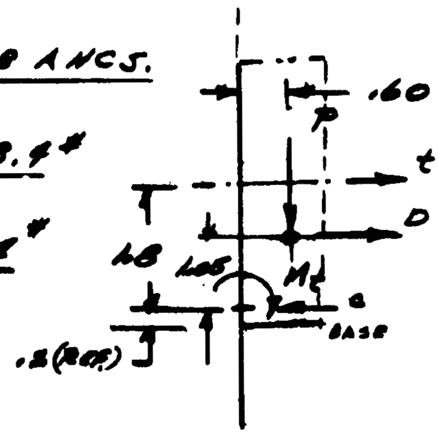
LONG TOWER LOADS ARE CRITICAL-

SCREW TENSION 1/4-28 ANCS.

$P_{MAX} = {}^{*}1246.7(2) = \underline{2493.4^{\#}}$

$D_{MAX} = {}^{*}608.8/2 = \underline{304.4^{\#}}$

*(REF. PGS. A.7 & A.8)



LOAD SKETCH

$t = M_t / 2(1.8)$

$M_t = P(.60) + D(1.05)$

$= 2493.4(.60) + 304.4(1.05) = \underline{1816}$ ''#

$t = 1816 / 3.6 = \underline{504^{\#}}$

$T = 5792^{\#}$ (REF. 1)

$M.S. = \dfrac{5792}{5(504)} - 1 = \underline{\underline{1.29}}$

7121-01078

-5 TOWER BLOCK (CONT.)

5/8" A.D. PINS -

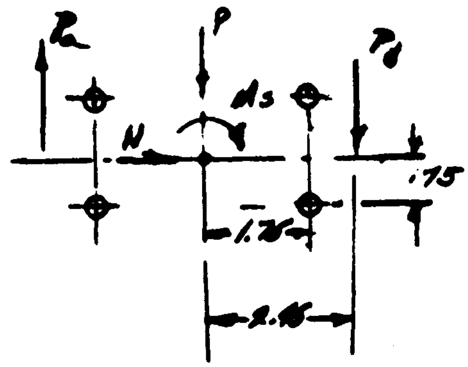
$P_d = \underline{1246.7}^{\#}$

$P_e = \underline{1233.9}^{\#}$ } (REF. PG. A.7)

$N = 608.8/2 = \underline{304.4}^{\#}$

$P = P_d - P_e = 1246.7 - 1233.9$

$= \underline{12.8}^{\#}$



$M_s = (P_d + P_e)(2.45) = (1246.7 + 1233.9)(2.45)$

$= \underline{6077.5}\ ''^{\#}$

$I_p = 4[(.75)^2 + (1.75)^2] = \underline{14.5}\ in^4/in^2$

$a = [(1.75)^2 + (.75)^2]^{1/2} = \underline{1.90}"$

$P_1 = N/4 + M(a)/I_p$

$= 304.4/4 + 6077.5(1.90)/14.5 = \underline{873}^{\#}$ (CONSER).

$P = \underline{15,895}^{\#}$ (REF. 1)

$M.S. = \dfrac{15.895}{5(.873)} - 1 = \underline{\underline{2.64}}$

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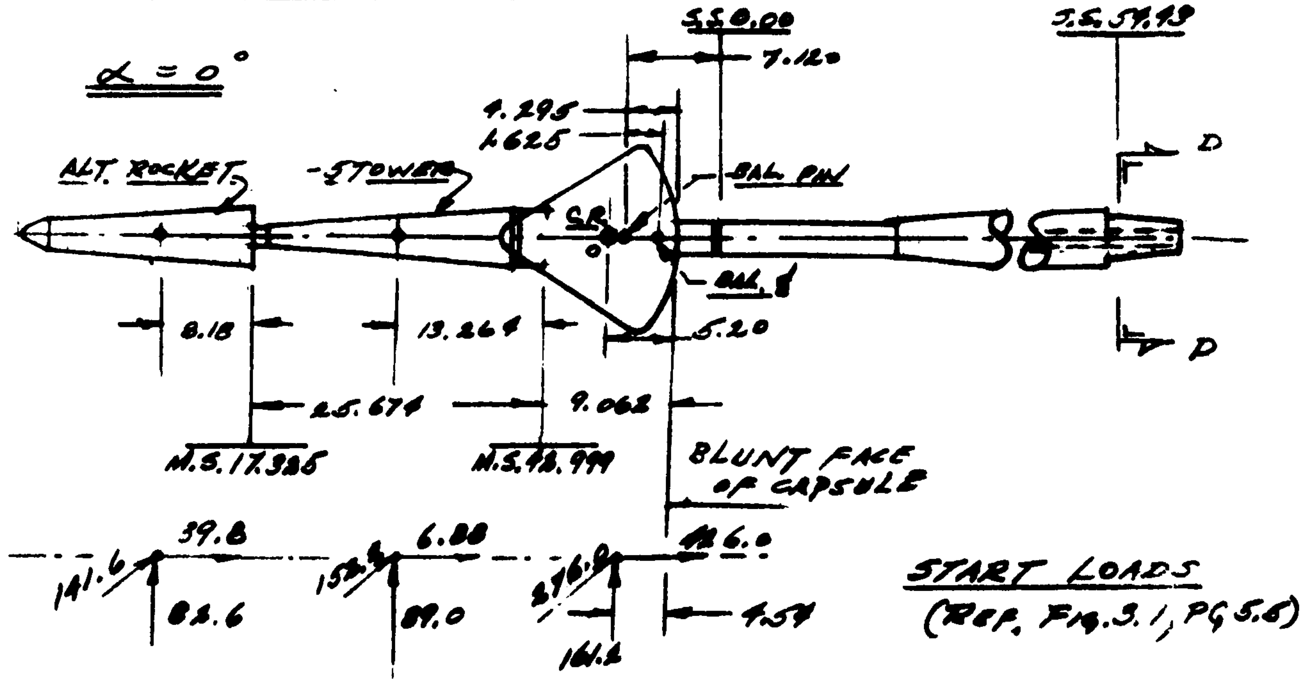
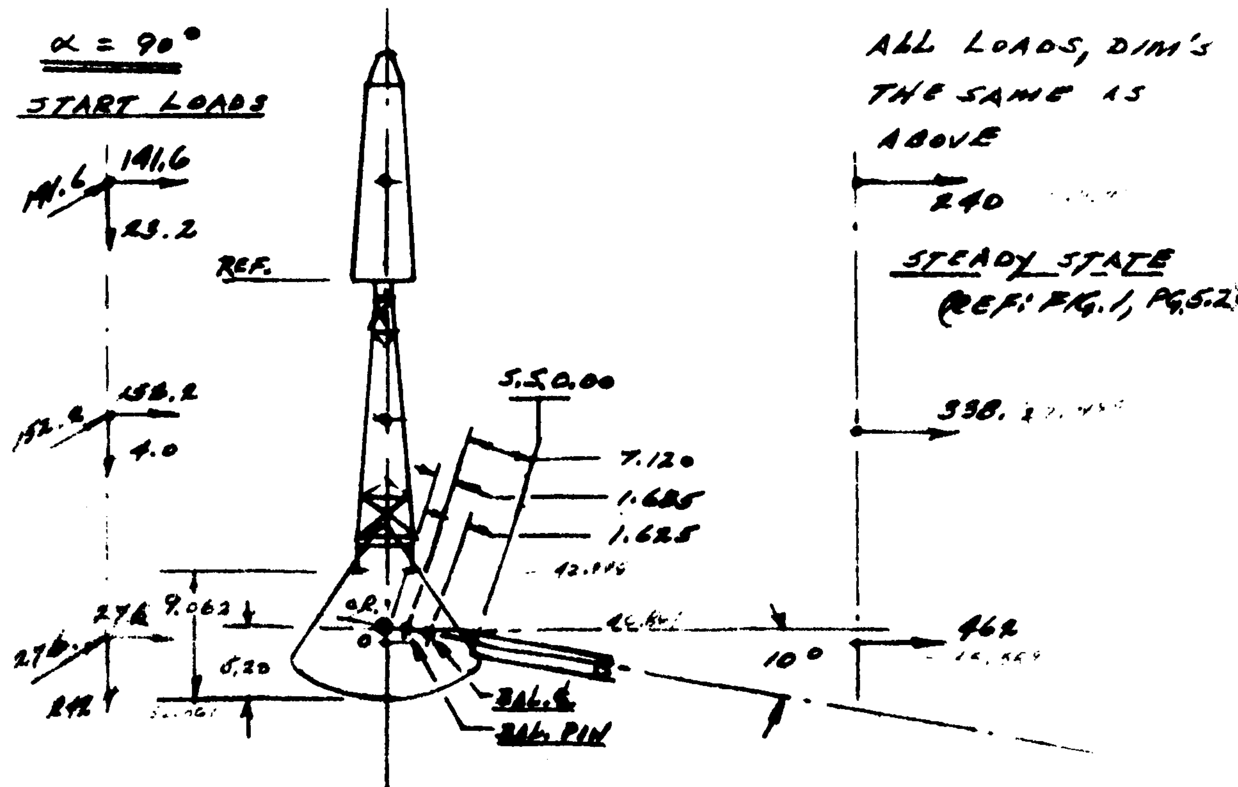
7121-01081

AMES STING LOADING:-





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7121-01081

AMES STING

MAX. MOMENT STUDY:

$\alpha = 0°$, START

$$M_{x_{DD}} = 82.6(8.18+25.674+9.062+7.120-4.295+54.43)$$
$$+ 89.0(13.264+66.317)$$
$$+ 161.2(4.54+7.120-4.295+54.43)$$
$$= 8274.1 + 7082.7 + 9961.4$$
$$= \underline{25,318.2}_{(W)} \text{ "\#}$$

$$M_{y_{DD}} = 141.6(100.17) + 152.2(79.581) + 276.0(61.795)$$
$$= 14,184.1 + 12,112.2 + 17,055.4$$
$$= \underline{43,351.7}_{(S)} \text{ "\#}$$

$$M_{DD} = \left[(M_x)^2 + (M_y)^2\right]^{\frac{1}{2}} = \left[(25,318.2)^2 + (43,351.7)^2\right]^{\frac{1}{2}}$$
$$= (2,520 \times 10^6)^{\frac{1}{2}} = \underline{\underline{50,203}} \text{ "\#}$$

$\alpha = 0°$, STEADY STATE

DRAG LOAD ONLY, = 565.3 < 800# FOR BALANCE ∴ NOT CRITICAL.

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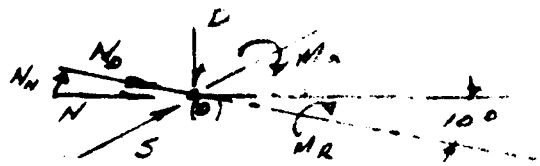
7121-01081

AMES STING -

MAX. MOM. STUDY (CONT.)

$\alpha = 90°$, START



$$M_{x_0} = 141.6\,(8.18 + 25.674 + 9.062 - 5.20)$$
$$+ 152.2\,(13.264 + 9.062 - 5.20)$$
$$+ 276.0\,(4.54 - 5.20)$$
$$= 5{,}340.6 + 2{,}606.6 - 182.2$$
$$= \underline{7{,}765.0}\ {}''\# = \underline{M_{x_0}\ (MAX)}$$

$$M_{Y_0} = M_{x_0} = \underline{\underline{7765.0}}\ {}''\# = \underline{\underline{M_R\ (MAX.)}}$$

$$N = 141.6 + 152.2 + 276.0 = \underline{569.8}\ \#$$

$$S = N = \underline{569.8}\ \#$$

$$D = 23.2 + 4.0 + 249.0 = \underline{276.2}\ \#\ \text{(ASSUME } \uparrow)$$

$$M_{DD} = \left\{\left[M_{x_0} + N(\sin 10°)(63.24) - D(\cos 10°)(63.24)\right]^2 + \left[S(63.24)\right]^2\right\}^{\frac{1}{2}}$$
$$= \left\{\left[7765.0 + 569.8(63.24)(.1736) + 276.2\,(63.24)(.9848)\right]^2\right.$$
$$\left. + \left[569.8\,(63.24)\right]^2\right\}^{\frac{1}{2}} = (2{,}273 \times 10^6)^{\frac{1}{2}} < \underline{M_{DD}\ \alpha = 0°}$$

7121-01081

AMES STING.

MAX. MOM. STUDY (CONT.)

$\alpha = 90°$, STEADY STATE

$M_{x_0} = 240\,(37.879) + 338\,(17.372) + 462\,(-1.728)$

$= \underline{14{,}644}$ "#

$M_{Y_0} = \underline{0.0}$

$N = 1040.0$ #

$S = D = \underline{0.0}$

$M_{00} = 14{,}644 + 1040\,(.1736)(63.24)$

$= \underline{26061.6}$ "# $<$ M_{00} ($\alpha = 0°$, START.)

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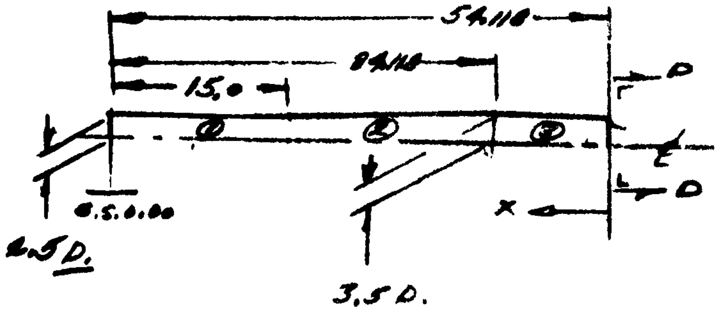
7121-01081

STARTING LOAD ON STING:-



AREA & C.P.

ITEM	A	x	Ax
1	37.50	46.62	1748.25
2	57.35	29.56	1695.27
3	70.00	10.00	700.00
	164.85		4143.52

$$\bar{X} = \frac{\Sigma Ax}{\Sigma A} = \frac{4143.52}{164.85} = \underline{25.13''}$$

$$P_N = 164.85(1.215) = \underline{200.3^{\#}}$$

$$P_S = 164.85(2.08) = \underline{342.9^{\#}}$$

$$M_{DDN} = 200.3(25.13) = \underline{5033.5''^{\#}}$$

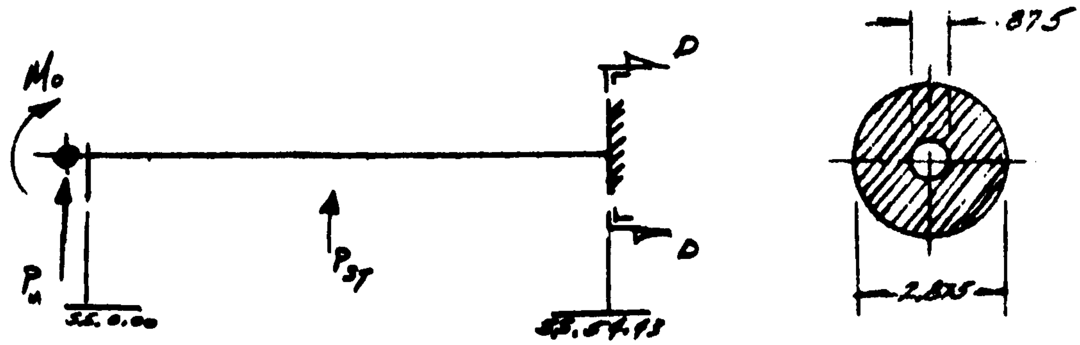
$$M_{DDS} = 342.9(25.13) = \underline{8617.1''^{\#}}$$

7121-.01041

AMES STING -

MAT'L - ARMCO 17-4PH
H.T. 190-210 K.S.I.

SECTION AT ADAPTER GAGE FACE (SS 54.43)



SECT.

$Z = .09817(d^4 - d_1^4)/d$

$= .09817(2.875^4 - .875^4)/2.875$

$= \underline{2.3129}$ $''^3$

$A = .7854(d^2 - d_1^2)$

$= \underline{5.8905}$ $''^2$

$M_{0D} = [(25,818.2 + 5033.5)^2 + (43,851.7 + 8617.1)^2]^{\frac{1}{2}}$

$= \underline{60,183}$ $''\#$

$f_b = \frac{Mc}{I} = \frac{60183(1.437)}{2.3129} = \underline{37,390}$ $\#/''^2$

$F_B = \underline{280\ KSI}$

$R_b = \frac{5(37390)}{280} = \underline{668}$

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7121-01081

AMES STING -

$$P_{D_H} = 82.6 + 89.0 + 161.2 + 200.3 = \underline{533.1}^{\#}$$

$$P_{D_S} = 141.6 + 152.2 + 276.0 + 342.9 = \underline{912.7}$$

$$P_D = \left[(533.1)^2 + (912.7)^2\right]^{\frac{1}{2}} = \underline{1057.}^{\#}$$

$$f_s = P/A = \frac{1057.0}{5.89} = \underline{\underline{179.5}}\ ^{\#}/_{\text{in}^2}$$

N.C.

$$M.S. = \frac{1}{.668} - 1 = \underline{\underline{.50}}$$

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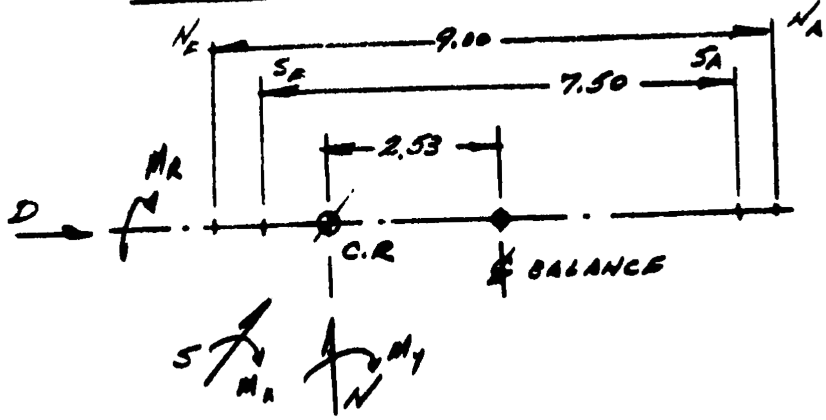
(AEDC) 3201580
(NAA) 7121-01083

AMES BALANCE STUDY -

$\alpha = 0°$, START



$N = \underline{332.8}$ #
** $D = \underline{565.3}$ #
$S = \underline{569.8}$ #
$M_Y = \underline{776...}$ "#
$M_R = -$
$M_X = 7765.0(.584)^*$
$= \underline{4535}$ "#

$$M_{X_{℄}} = 332.8(2.530) + 4535$$
$$= \underline{5377.} \text{ "\#}$$

$$M_{Y_{℄}} = 569.8(2.530) + 7765$$
$$= \underline{9207} \text{ "\#}$$

$$P_{NF_{(MAX)}} = (332.8)/2 + 5377/9.00 = 763.8 \text{ \#}$$

$$P_{SF_{(MAX)}} = 569.8/2 + 9207/7.50 = 1512.5 \text{ \#}$$

$$\text{S.F. ON RATED LOADS} \begin{cases} 2500/763.8 = 3.27 \\ 1000/1512.5 = .661 \end{cases}$$

$$\text{CRITICAL M.S.} = .661 - 1 = \underline{\underline{-.34}}$$

NOTE: IF THE BAL. IS ROLLED 90° NO OVERLOAD CONDITION WILL OCCUR.

* RATIO, NORMAL TO SIDE, START LOADS
** (MAX.) STEADY STATE (REF. PG. A.25)

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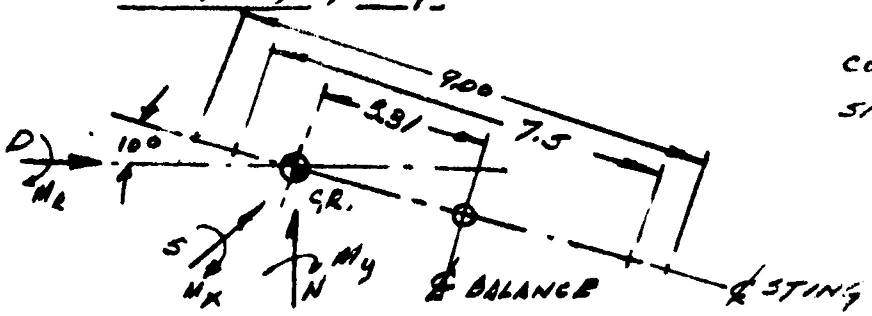
DATE: 3-7-62	APOLLO FORCE MODEL	MODEL NO.

(AEDC) 3201580
(NAA) 7121-01083

AMES BALANCE STUDY -

$\alpha = 90°$; START



COS 10° = .9848
SIN 10° = .1736

$\overset{*}{N} = 1.426(1.215)(144)$
$= \underline{249.5}^{\#}$
$D = \underline{569.8}^{\#}$
$S = \underline{569.8}^{\#}$
$M_Y =$ —
$M_R = \underline{7765.0}''^{\#}$
$M_X = \underline{7765.0}''^{\#}$

* NORMAL LOAD ON BLUNT FACE OF MODEL (START)

$M_{X_{℄}} = 7765.0 + 569.8(.1736)(3.31)$
$+ 249.5(.9848)(3.31) = \underline{8905.7}''^{\#}$

$M_{Y_{℄}} = 569.8(3.31) + 7765.0(.1736) +$ —
$= \underline{3234}''^{\#}$

$M_R = 7765.0(.9848) = \underline{7647.0}''^{\#}$

$P_{N_{F(MAX)}} = [249.5(.9848) + 569.8(.1736)]/2$
$+ 8905.7/9.0 = \underline{1161.8}^{\#}$

$P_{S_{F(MAX)}} = 569.8/2 + 3234/7.50 = \underline{716.1}^{\#}$

$D = 569.8(.9848) + 249.5(.1736) = \underline{604.5}^{\#}$

S.F. ON RATED LOADS
- 2500/1161.8 = 2.15
- 1000/716.1 = [illegible]
- 800/604.5 = [illegible] 32
- 400 [illegible] [illegible]

CRITICAL M.S. = .529 [illegible] .477

APPENDIX B

MODIFICATIONS FOR DUAL BALANCE TEST

REMARKS

This appendix presents a structural analysis of the components of the FS-2 Apollo force model that have been modified or added for a dual balance test. Testing will be conducted in the Ames Unitary Plan Wind Tunnel facilities.

Two load conditions are studied: starting loads at 40 degrees angle of attack and running loads at 50 degrees angle of attack. All components are analyzed for the load condition that is most critical in each case. All components have positive margins of safety for a safety factor of 5 on material ultimate.

All drawings are NAA/S&ID drawn in July 1962 and are given in the following listing.

7121-01077	Assembly and Details—Command Module
7121-01078	Details—Balance Blocks and Miscellaneous
7121-01079	Assembly and Details—Launch Escape Tower
7121-01081	Sting—Ames Wind Tunnel
7121-01086	Model Installation—Ames Unitary Tunnel
7121-01087	Assembly and Details Indexed Sting Joint
7121-01089	Assembly and Details Rocket Motors

Margins of safety for the components are as follows:

Page	Component	Type of Stress	Margin of Safety
B-9	-4 Balance adaptor	Bending	High
B-12	-4 Tower leg support	Shear	2.59
B-12	Leg Support pins	Shear	2.50
B-13	Leg Support bolts	Tension	High
B-13	-7 Splice plate	Bending	1.20
B-20	-9 Spacer pins	Shear	1.75
B-21	-9 Spacer bolts	Tension	4.84
B-26	-2 Support arm	Bending	2.07
B-28	-2 Pivot pins	Shear	3.76
B-29	-2 Support bolts	Tension	1.16
B-32	-6 Sting adapter (C-C)	Bending	3.41
B-34	-6 Sting adaptor (D-D)	Bending	1.45
B-35	Ames sting	Bending	0.46

WTL-62-146
ENCLOSURE 2

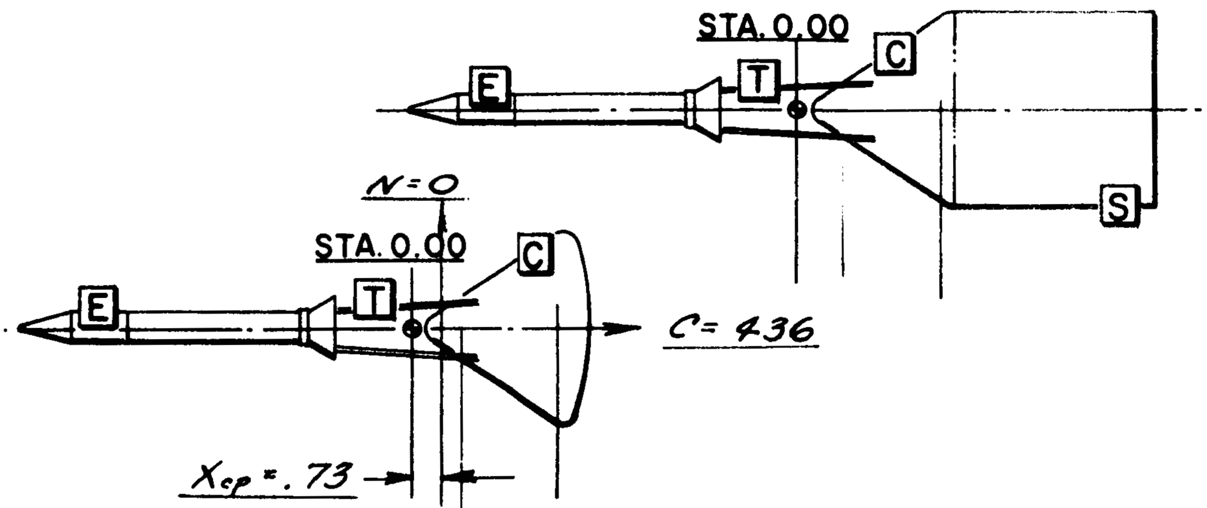
LOADS, APOLLO — WIND TUNNEL MODEL

MODEL APOLLO FS-2
SCALE .105
TUNNEL UPWT-AMES
TEMP.
MACH NO. .7 TO 3.5
q = 540 PSF
α = 0°
STEADY STATE LOADS — ☒
TRANSIENT LOADS — ☐

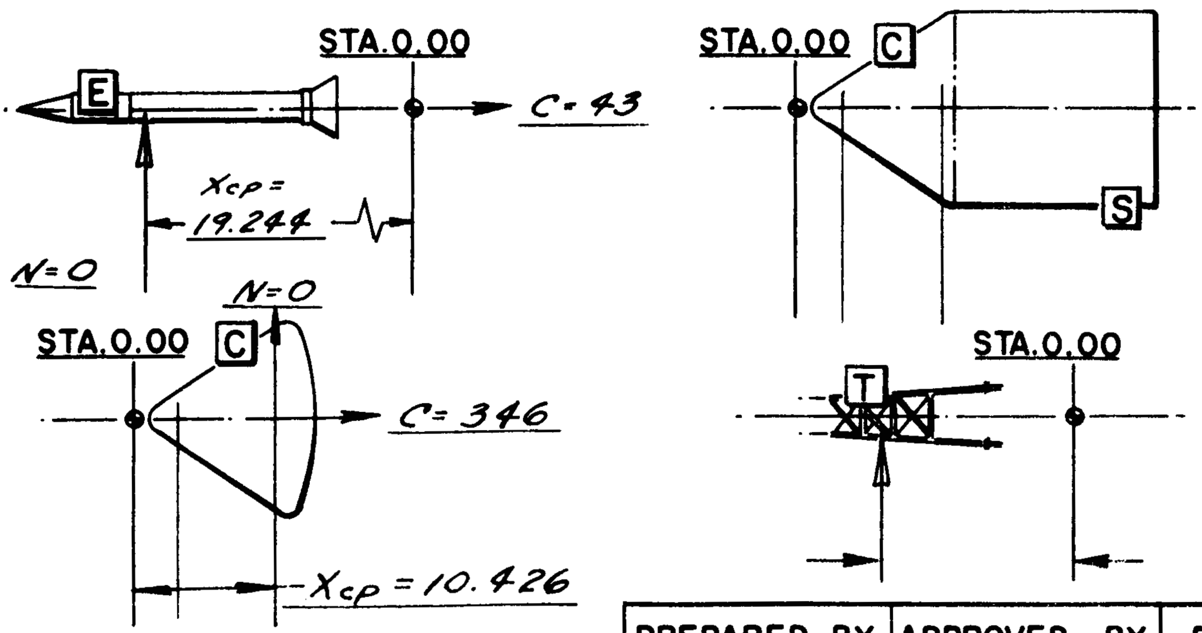
REQUIRED SAFETY FACTORS:—
5 ON ULTIMATE
3 ON YIELD

NOTES:—
(1)—LOADS GIVEN IN POUNDS. DIMS. IN INCHES, (MODEL SCALE).
(2)—

TOTAL CONFIGURATION LOADS:



LOADS ON COMPONENTS:



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WTL-62-146
ENCLOSURE 2 - CONT.

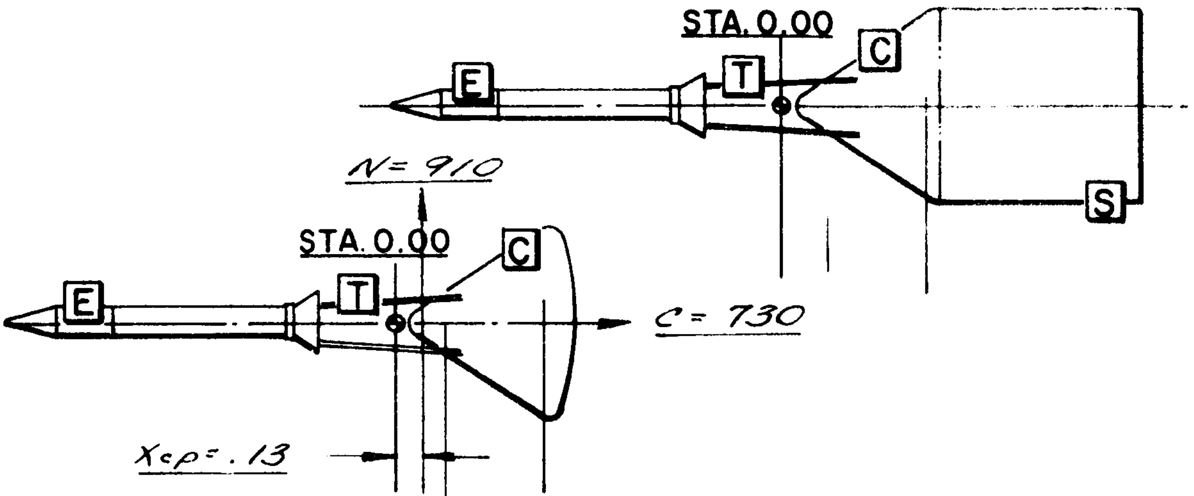
LOADS, APOLLO — WIND TUNNEL MODEL

MODEL Apollo FS-2
SCALE .105
TUNNEL UPWT-AMES
TEMP.
MACH NO. .7 TO 3.5
q = 540 PSF
α = 50°
STEADY STATE LOADS — ☒
TRANSIENT LOADS — ☐

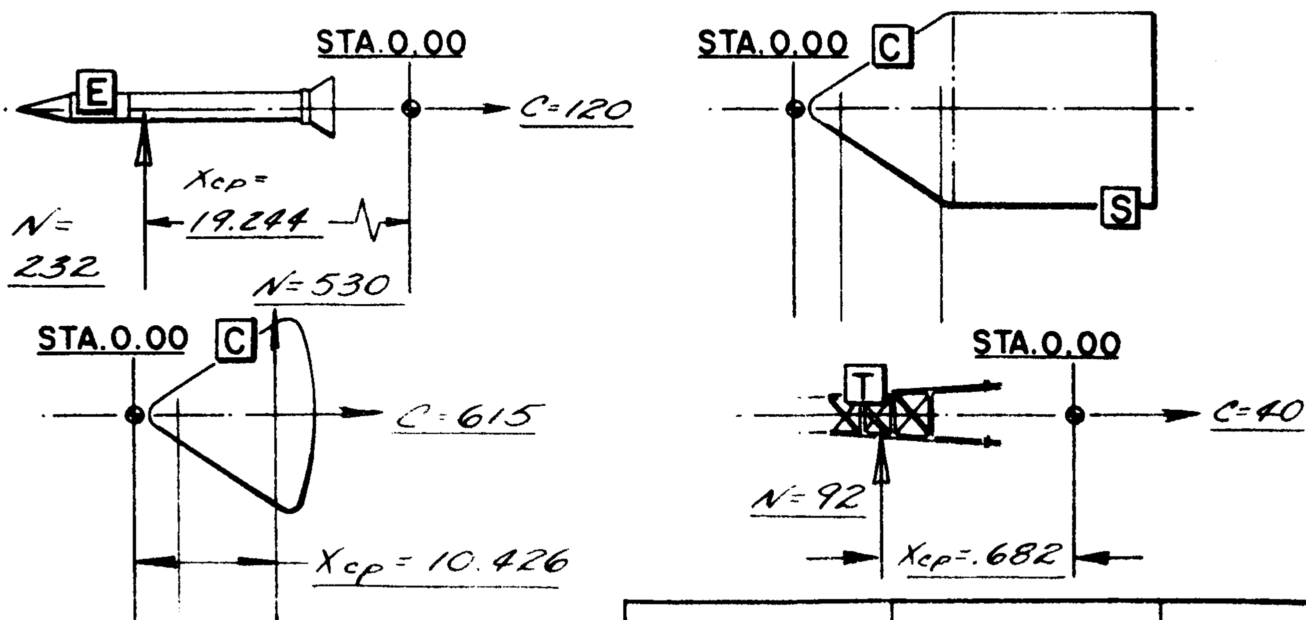
REQUIRED SAFETY FACTORS:—
5 ON ULTIMATE
3 ON YIELD

NOTES:—
(1)-LOADS GIVEN IN POUNDS. DIMS. IN INCHES, (MODEL SCALE).
(2)-

TOTAL CONFIGURATION LOADS:



LOADS ON COMPONENTS:



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	SHEET 7 OF	

WTL - 62 - 146
ENCLOSURE 3

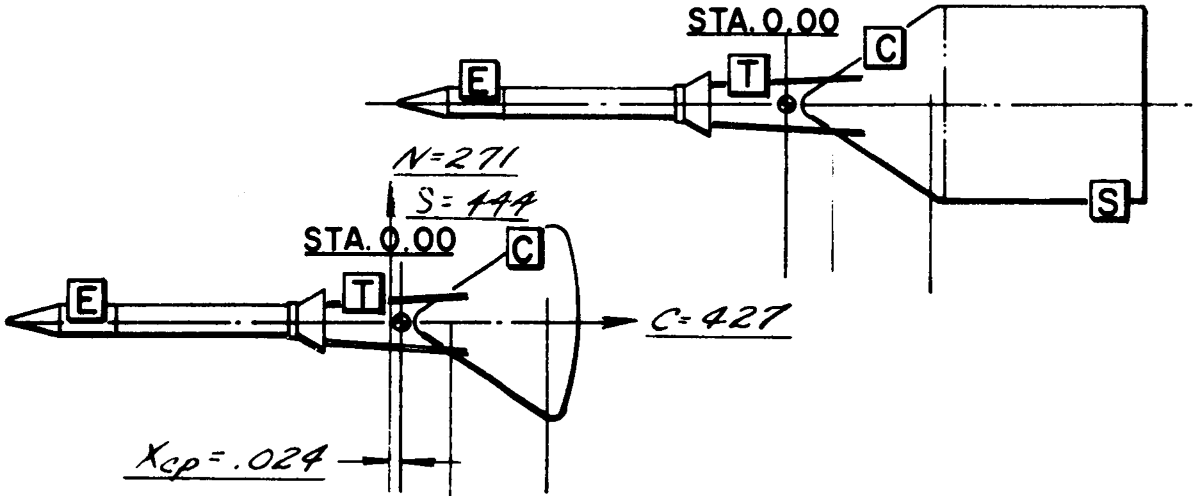
LOADS, APOLLO — WIND TUNNEL MODEL

MODEL APOLLO FS-2
SCALE .105
TUNNEL UPWT - AMES
TEMP.
MACH NO. .7 TO 3.5
q = 1.215 & 2.08 PSI
α = 0°
STEADY STATE LOADS — ☐
TRANSIENT LOADS — ☒

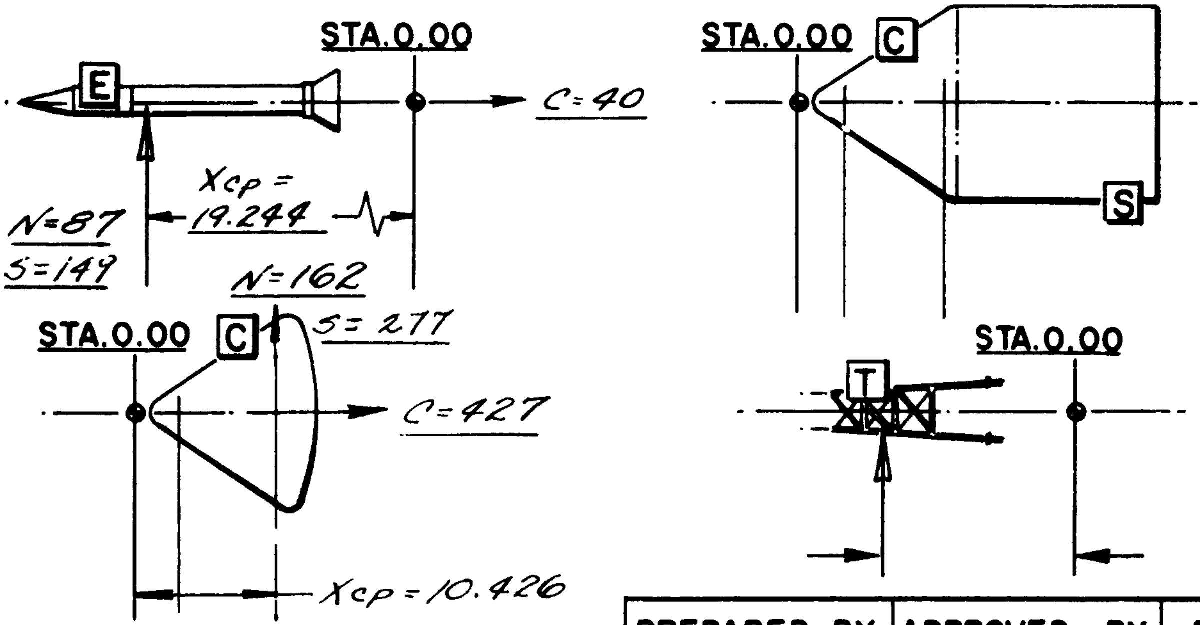
REQUIRED SAFETY FACTORS:—
5 ON ULTIMATE
3 ON YIELD

NOTES:—
(1)—LOADS GIVEN IN POUNDS. DIMS. IN INCHES, (MODEL SCALE).
(2)—

TOTAL CONFIGURATION LOADS:



LOADS ON COMPONENTS:



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	SHEET 8 OF	

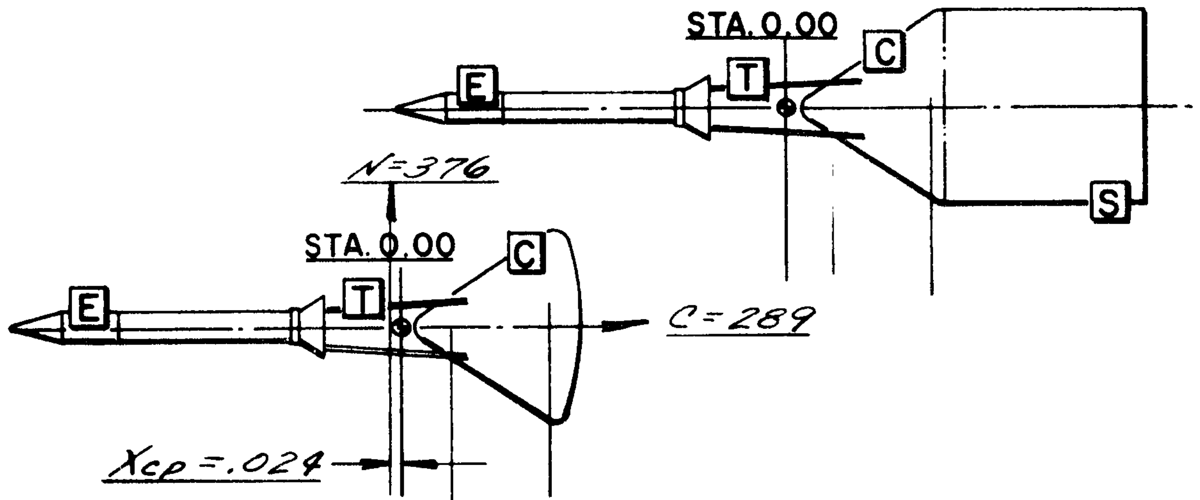
LOADS, APOLLO — WIND TUNNEL MODEL

MODEL Apollo FS-2
SCALE .105
TUNNEL UPWT - AMES
TEMP. ______
MACH NO. .7 TO 3.5
q = 1.215 & 2.08 PSI
α = 20°
STEADY STATE LOADS — ☐
TRANSIENT LOADS — ☒

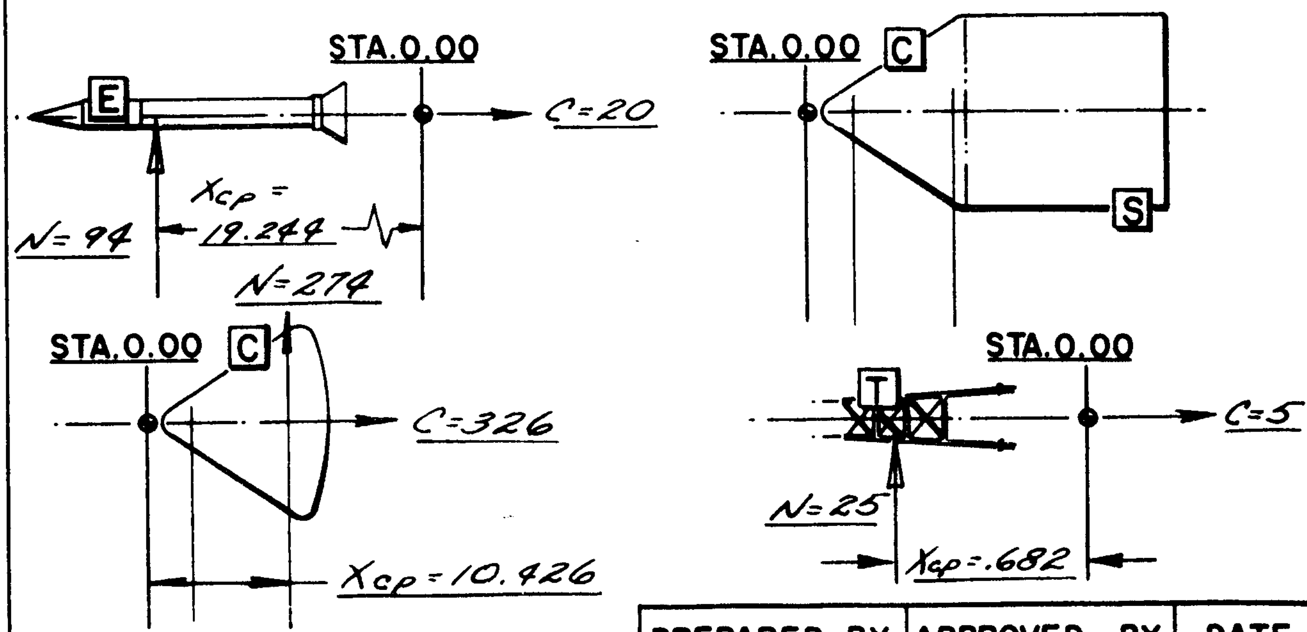
REQUIRED SAFETY FACTORS:—
5 ON ULTIMATE
3 ON YIELD

NOTES:—
(1)- LOADS GIVEN IN POUNDS. DIMS. IN INCHES, (MODEL SCALE).
(2)- ______

TOTAL CONFIGURATION LOADS:



LOADS ON COMPONENTS:



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	SHEET 9 OF	

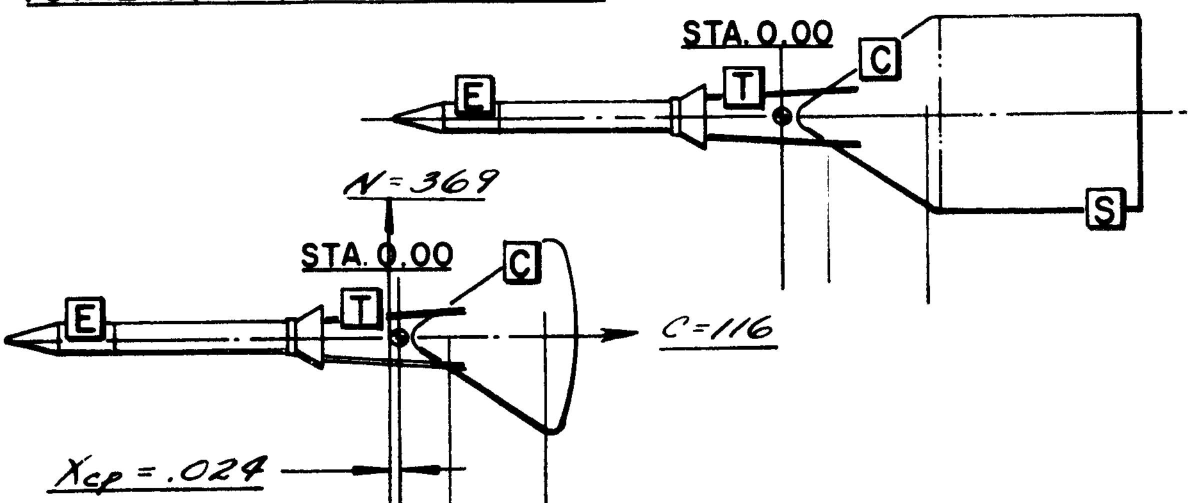
LOADS, APOLLO — WIND TUNNEL MODEL

MODEL Apollo FS-2
SCALE .105
TUNNEL UPWT-AMES
TEMP.
MACH NO. .7 TO 3.5
q = 1.215 & 2.08 PSI
α = 40°
STEADY STATE LOADS — ☐
TRANSIENT LOADS — ☒

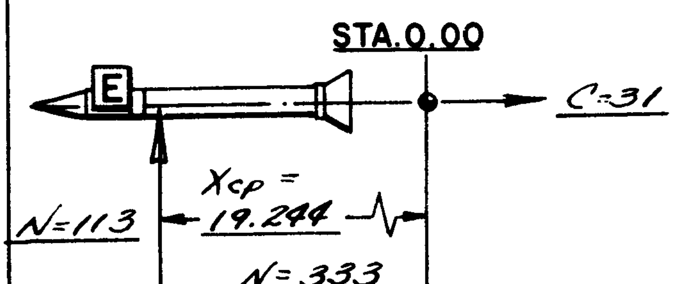
REQUIRED SAFETY FACTORS: —
5 ON ULTIMATE
3 ON YIELD

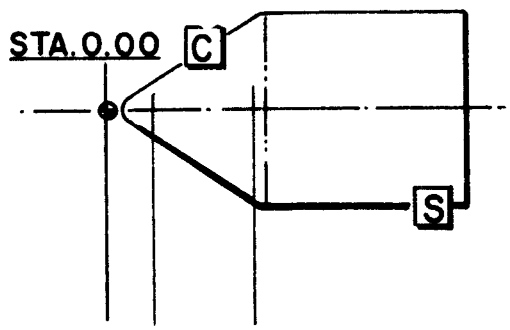
NOTES: —
(1) — LOADS GIVEN IN POUNDS. DIMS. IN INCHES, (MODEL SCALE).
(2) —

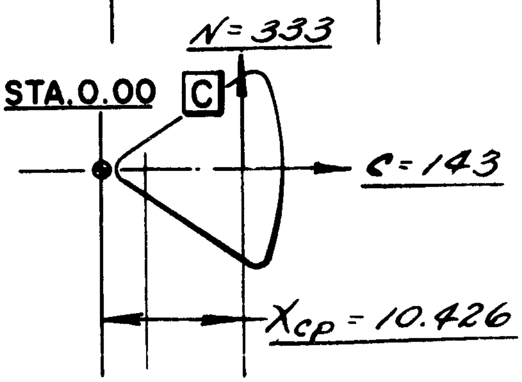
TOTAL CONFIGURATION LOADS:

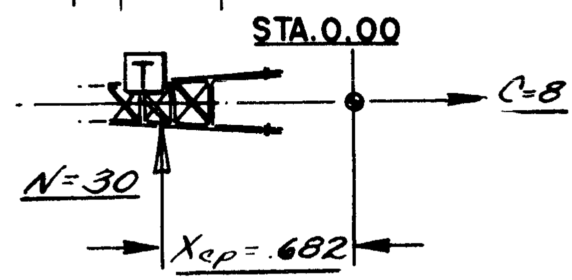


LOADS ON COMPONENTS:









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	SHEET 10 OF	

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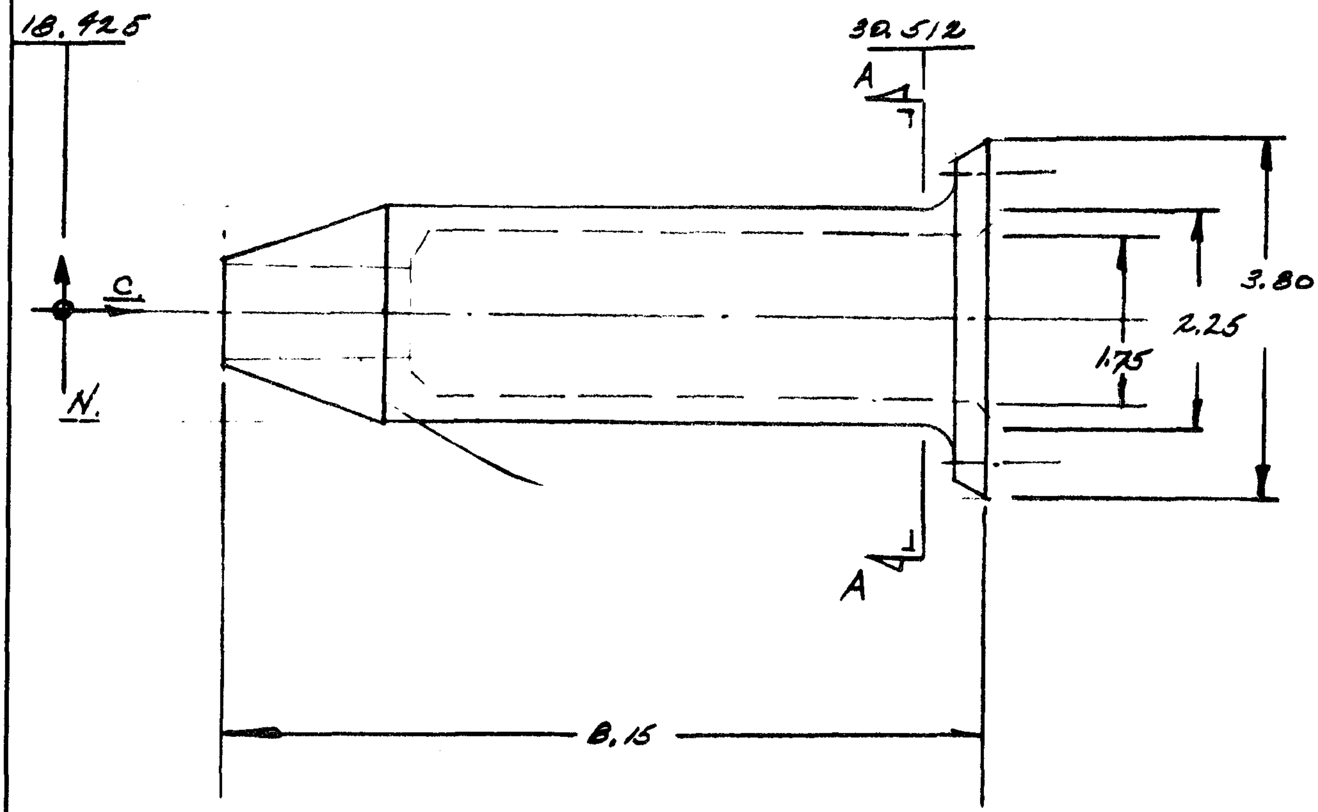
-4 BALANCE ADAPTOR -



LOADS-

RUNNING- ($\alpha = 50°$)

N= 232 , C = 120 LB.

STARTING ($\alpha = 40°$)

N= 149 + 113 = 187 LB

C= 31 LB.

MAT'L - 17-4PH CRES

(H.T. 190-210 KSI.)

7121-01089

-4 BALANCE ADAPTOR (CONT.)

SECTION A-A; BENDING-

$$M = 232\,(30.512 - 18.425) = \underline{2804\ IN\text{-}LB.}$$

$$I_{xx} = .0491\left(2.25^4 - 1.75^4\right) = \underline{.7979\ IN^4}$$

$$A = .7854\left(2.25^2 - 1.75^2\right) = \underline{1.571\ IN^2}$$

$$f_b = \frac{Mc}{I} + \frac{P}{A} = \frac{2804(1.125)}{.7979} + \frac{120}{1.571}$$

$$= \underline{\underline{4030\ PSI.}}$$

$$M.S. = \frac{190}{5(4.03)} - 1 = \underline{\underline{HIGH.}}$$

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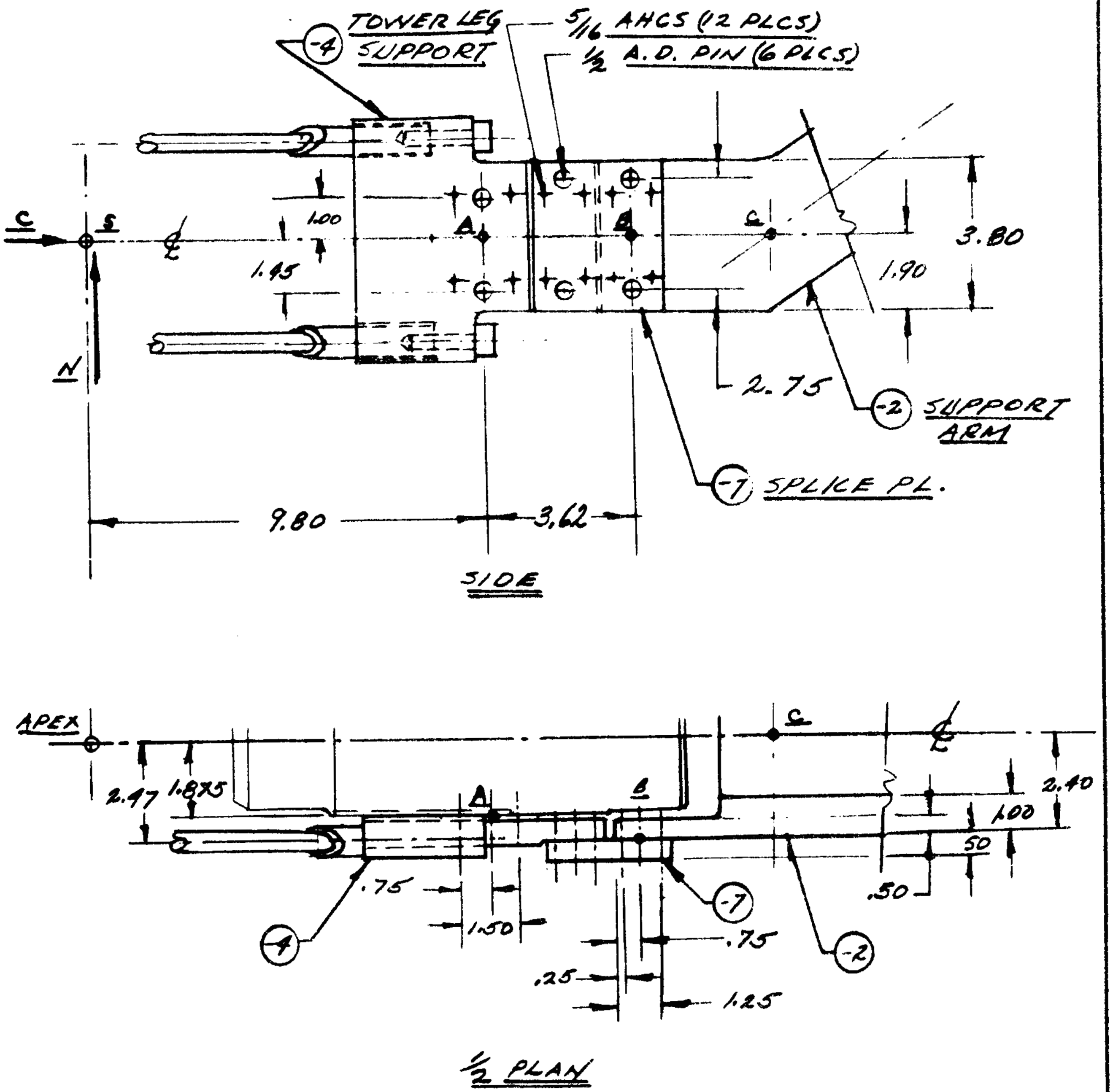
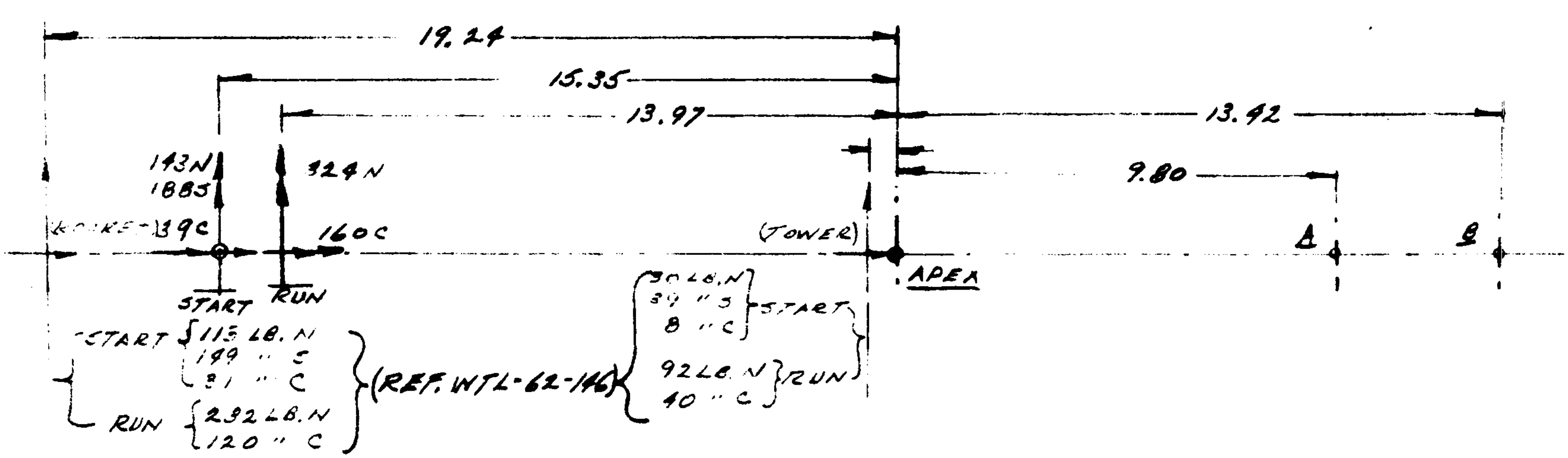
TOWER LEG SUPPORT & SPLICE PLATES



ROCKET ℄ TOWER SUPPORT STRUCTURE -

NORMAL, SIDE ℄ CHORD STARTING LOAD GEOMETRY.

NORMAL ℄ CHORD RUNNING LOAD GEOMETRY.



MOMENTS ℄ LOADS AT A ℄ B.

	STARTING (α = 40° CRITICAL) POINT A	POINT B	RUNNING (α = 50° CRIT.) POINT A	POINT B
M_N =	9596 IN-LB.	4114	7703	8875
M_S =	4728	5409	—	—
N =	143 LB.	143	324	324
S =	188	188	—	—
C =	39	39	160	160

7121- 01087

-4 TOWER LEG SUPPORT-

PINS, SUPPORT TO BALANCE BLOCK.

SHEAR- ½ IN. A.D. PIN.

$P = M_N / 2(d)$, $M_N(MAX) = 7703$ IN-LB. (REF. PG. 14)

$d = 1.00 + 1.45 = 2.45$ (REF PG. 13)

$= 7703 / 2(2.45)$

$= 1,572$ LB./PIN.

P(½ IN. A.D) = 28,260 LB. (REF. 1.)

$$M.S. = \frac{28,260}{5(1572)} - 1 = 2.59$$

PINS, SUPPORT TO -2 SUPPORT ARM.

SHEAR - ½ IN. A.D. PIN.

$P = M_N / 2(d)$, $(M_N\ MAX) = 8875$ IN-LB. (PG. 14)

$d = 2.75$ (REF PG. 13)

$= 8875 / 2(2.75)$

$= 1614$ LB. / PIN.

$$M.S. = \frac{28,260}{5(1614)} - 1 = 2.50$$

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-4 TOWER LEG SUPPORT-

BOLTS, SUPPORT TO -2 SUPPORT ARM

TENSION- $\quad$ 5/16-24 A.H.C. SCREWS

$$t = (d/2)M_{s_e} / 2(2.40 - \tfrac{d}{2})(2)(c)$$

$$= .25(5409) / 4(1.0)(2.40 - .25)$$

$$= 1{,}352 / 4(2.15) = \underline{157 \text{ LB./SC.}}$$

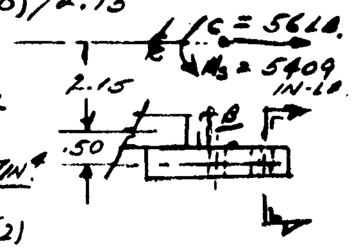
$$M.S. = \frac{9264}{5(157)} - 1 = \underline{HIGH}$$

BENDING- -7 SPLICE PLATE

MAT'L, 17-4PH (H.T. 190-210 KSI.)

$$M_x = M_{s_e}(.50)/2.15 = 5409(.50)/2.15$$

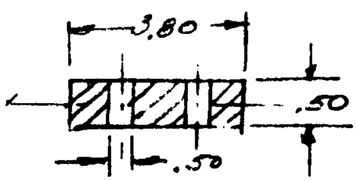
$$= 2516(.50) = \underline{1258 \text{ IN.LB.}}$$



$$I_{xx} = (.50)^3(3.80 - 1.00)/12 = \underline{.02917 \text{ IN}^4}$$

$$I_{yy} = [.50(3.80)^3 - 2(.5)^4]/12 - .25(1.375)^2(2)$$

$$= \underline{1.3301 \text{ IN}^4}$$



$$f_b = \frac{M_x c}{I_x} + \frac{P}{A} + \frac{M_y c}{I_y}$$

$$= \frac{1258(.25)}{.02917} + \frac{(2516 + 39/2)}{2.80(.50)} + \frac{4114(2.90)}{2(1.3301)} \quad \text{SECT.}$$

$$= \underline{17{,}080 \text{ PSI}}$$

$$M.S. = \frac{190}{5(17.1)} - 1 = \underline{1.20}$$

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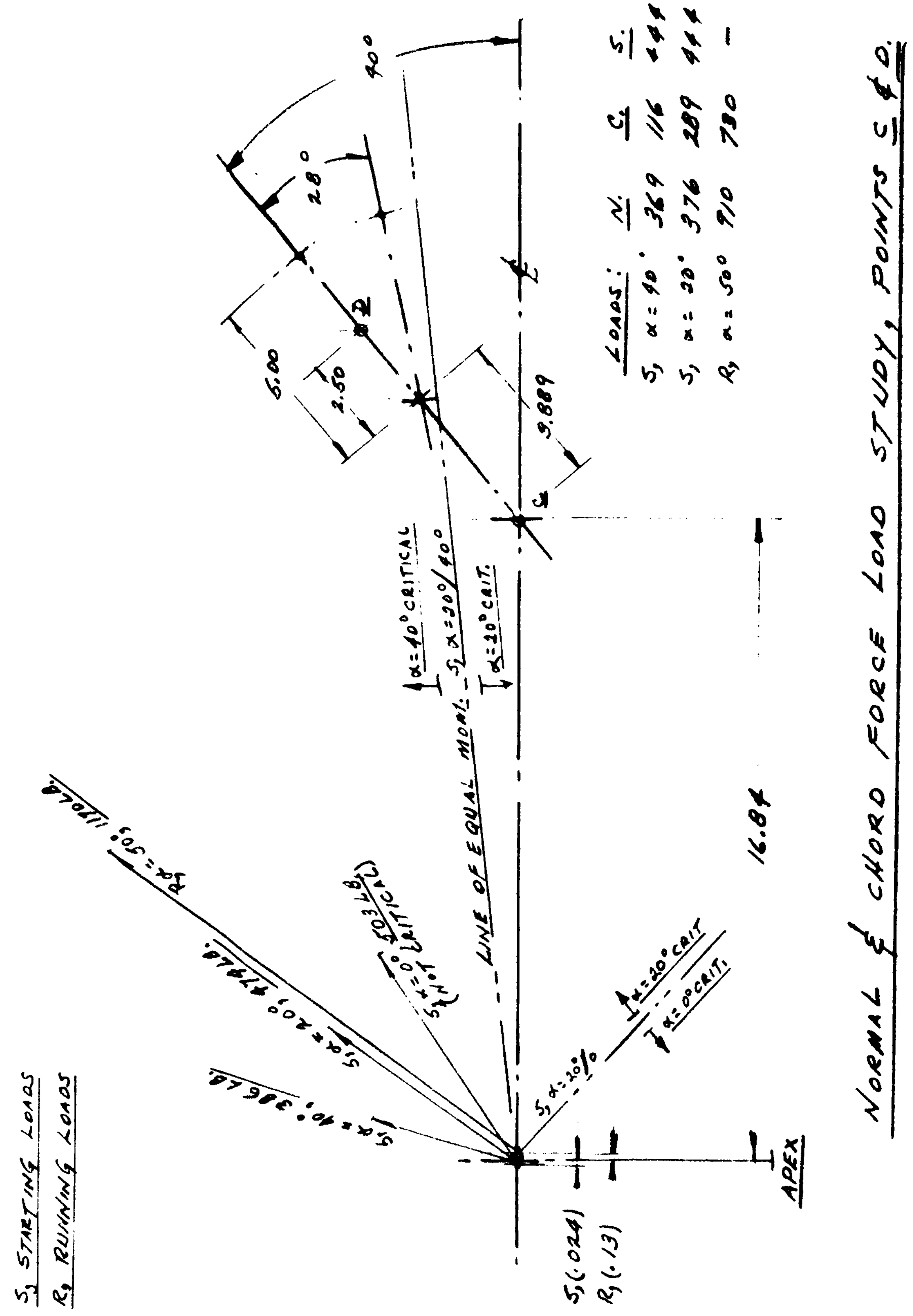

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-9 SPACER

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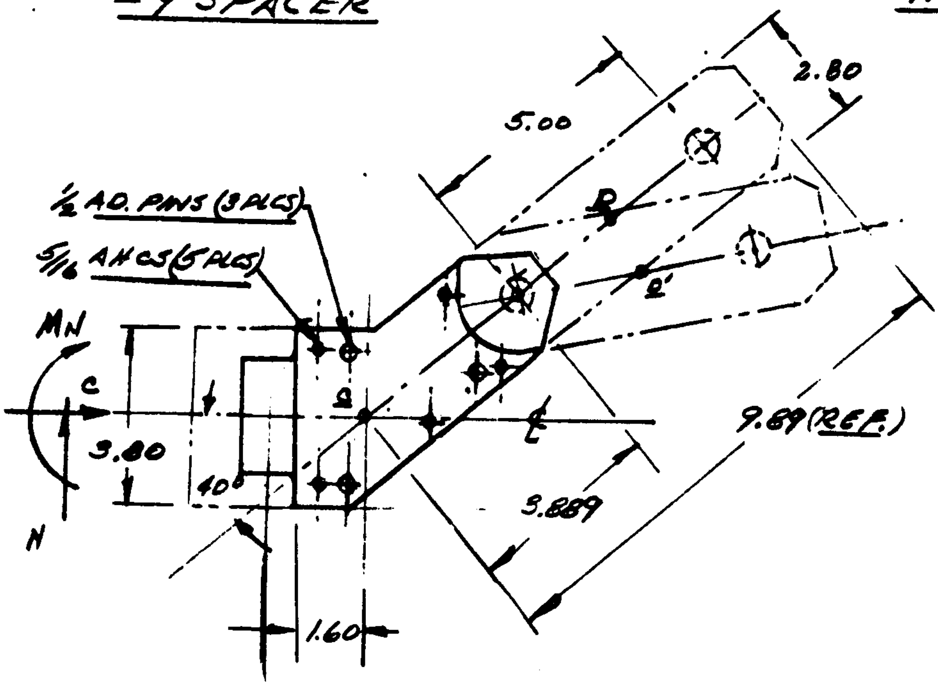
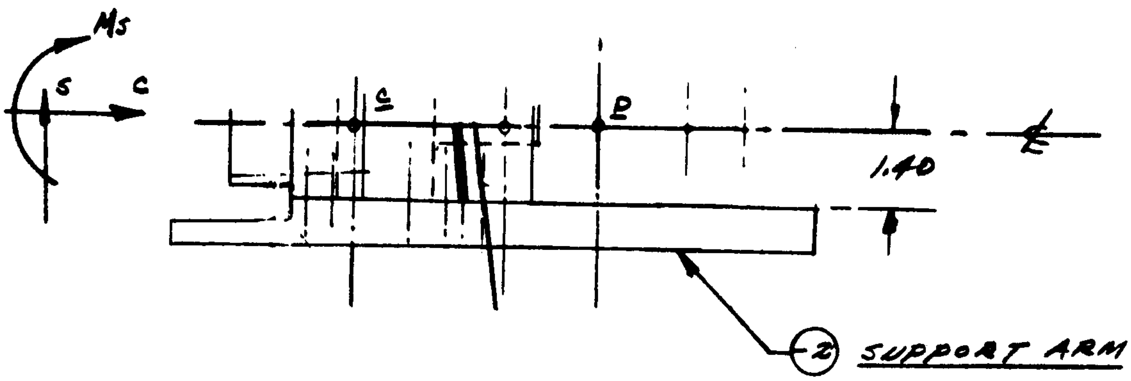


SIDE

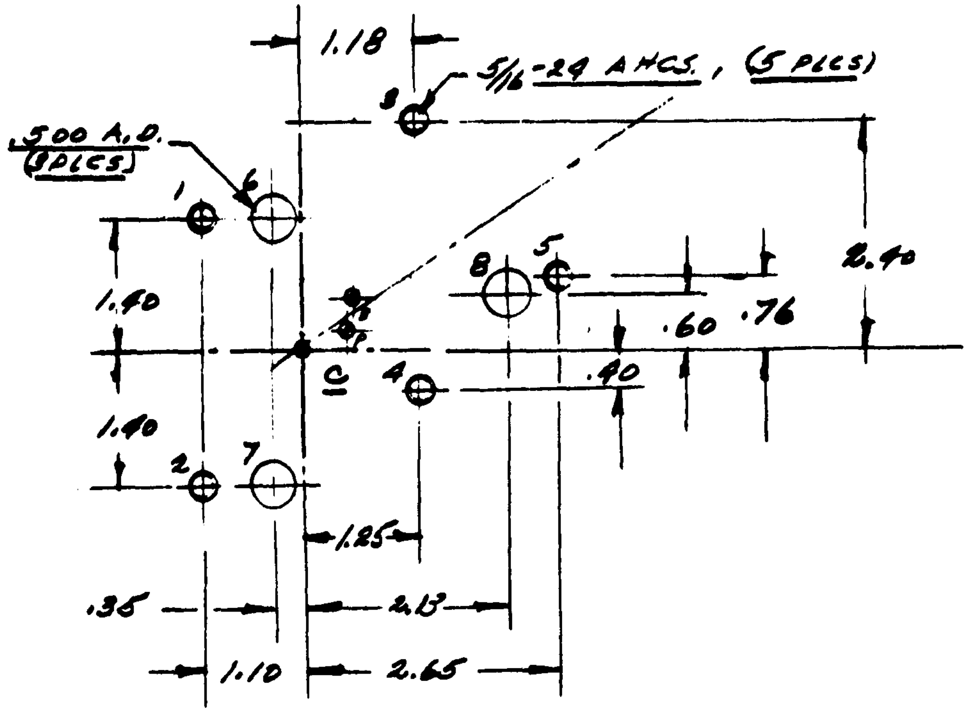


1/2 PLAN

7121-01087

-9 SPACER - (CONT.)

ATTACHMENTS - 2 ARM TO -9 SPACER - PATTERN PROPERTIES



ITEM	Ax	Ax²	Ay	Ay²
1	-1.10	1.21	+1.40	1.96
2	-1.10	1.21	-1.40	1.96
3	+1.18	1.392	+2.40	5.76
4	+1.25	1.563	-.40	.16
5	+2.65	7.023	+.76	.578
	+2.88	12.398	+2.76	10.418
6	-.35	.123	+1.40	1.96
7	-.35	.123	-1.40	1.96
8	+2.13	4.537	+.60	.36
	+1.43	4.783	+.60	4.28

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-9, SPACER (CONT.)

ATTACHMENT PATTERN (CONT.)-

BOLTS -

$$\bar{x}_B = \frac{\Sigma Ax}{\Sigma A} = \frac{+2.88}{5} = +.576$$

$$\bar{y}_B = \frac{\Sigma Ay}{\Sigma A} = \frac{2.76}{5} = +.552$$

$$I_{x_B} = 2\left[\Sigma Ay^2 - Ay(\bar{y})\right] = 2\left[10.418 - 2.76(.552)\right]$$
$$= 2(8.894) = 17.788$$

$$I_{y_B} = 2\left[\Sigma Ax^2 - Ax(\bar{x})\right] = 2\left[12.398 - 2.88(.576)\right]$$
$$= 2(10.739) = 21.478$$

$$A_B = 2(5.0) = 10.0$$

PINS -

$$\bar{x}_P = \frac{+1.43}{3} = +.477$$

$$\bar{y}_P = \frac{+.60}{3} = +.20$$

$$I_{x_P} = 2\left[4.28 - .60(.20)\right] = 2(4.160) = 8.320$$

$$I_{y_P} = 2\left[4.783 - 1.43(.477)\right] = 2(4.101) = 8.202$$

$$I_{xy_P} = I_{x_P} + I_{y_P} = 8.320 + 8.202 = 16.522$$

$$A_P = 2(3.0) = 6.0$$

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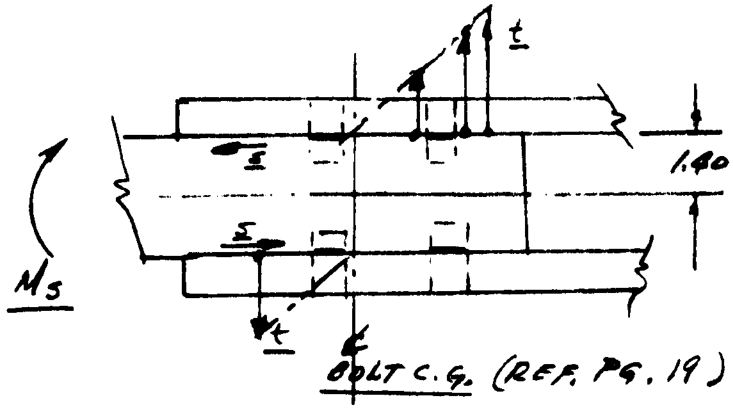
-9 SPACER (CONT.)

PERCENTAGE OF YAW MOMENT RESISTED BY PINS OR BOLTS -

$A_p = (.7854)(.50)^2$

$= \underline{.1964 \, IN^2}$

$A_B = \underline{.0579 \, IN^2}$
(REF. 1)



CONSERVATIVELY ASSUME ONLY ONE BOLT PATTERN IS ACTIVE AND THE AXIS OF RESISTANCE IS AT THE PATTERN C.G. ALSO ASSUME THE PERCENTAGE OF LOAD RESISTED BY THE PINS IS A DIRECT PROPORTION OF THE MOMENT OF INERTIA OF THE PINS TO THE SUM OF THE INERTIA OF THE PINS AND BOLTS.

$I_{PINS} = 2 A_p d'^2 = 2(3)(.1964)(1.40)^2 = \underline{2.3097} \, IN^4$

$I_{BOLTS} = A_B(10.739) = .0579(10.739) = \underline{.6218}$, (REF. PG. 20)

$\%_P = \dfrac{I_P}{(I_P + I_B)} = \dfrac{2.3097}{(2.3097 + .6218)} = \underline{.788}$

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-9 SPACER ATTACHMENT LOADS

PINS -

STARTING - ($\alpha = 20°$, CRITICAL)

$$M_{N_P} = 376(16.84 + .024 + .477) - 289(.29) = 6,460 \text{ IN-LB}$$

$$M_{S_P} = 444(17.34) = 7,700 \text{ IN-LB}$$

RUNNING - ($\alpha = 50°$, CRITICAL)

$$M_{N_P} = 910(17.34 - .024 - .13) - 730(.20) = 15,639 \text{ IN-LB}$$

$$M_{S_P} = 0.0 -$$

BOLTS - (ONLY RESIST SIDE LOADS)

STARTING -

$$M_{S_B} = 444(17.34 + .576 - .477) = 7,743 \text{ IN-LB}$$

7121-01087

-9 SPACER (CONT.)

SHEAR - (1/2 IN. A.D. PINS)

$$P_{s_1} = \left[\left(\frac{M_{x_N} c}{I_{xy_p}}\right)^2 + \left(\frac{M_{x_p} c}{I_{xy_p}} + \frac{M_{s_p}(\frac{1}{2})c}{I_{z_p}}\right)^2\right]^{\frac{1}{2}}$$

$$= \left\{\left[\frac{6460(2.65-.477)}{16.522}\right]^2 + \left[\frac{6460(.60-.20)}{16.522} + \frac{7700(.788)(1.40)}{11.79}\right]^2\right\}^{\frac{1}{2}}$$

$$= \left[(849)^2 + (156 + 720)^2\right]^{\frac{1}{2}}$$

$$= (1,488,177)^{\frac{1}{2}} = \underline{1220 \text{ LB./PIN}}$$

$$P_{R_1} = \frac{15,639(2.65-.477)}{16,522} = \underline{2056 \text{ LB/PIN}}$$

RUNNING LOAD MOST CRITICAL -

$$M.S. = \frac{28260}{5(2056)} - 1 = \underline{\underline{1.75}}$$

7121-01087

-9 SPACER (CONT.)

TENSION - (5/16 A.H.C. SCREWS)

$$t_B = \frac{(1-k)\, M_{S_B}(c)}{I_{Y_C}}$$

$$= \frac{(1-.788)(7743)(2.65-.576)}{10.739}$$

$$= 317 \text{ LB./SCREW}$$

$$M.S. = \frac{9264}{5(317)} - 1 = 4.84$$

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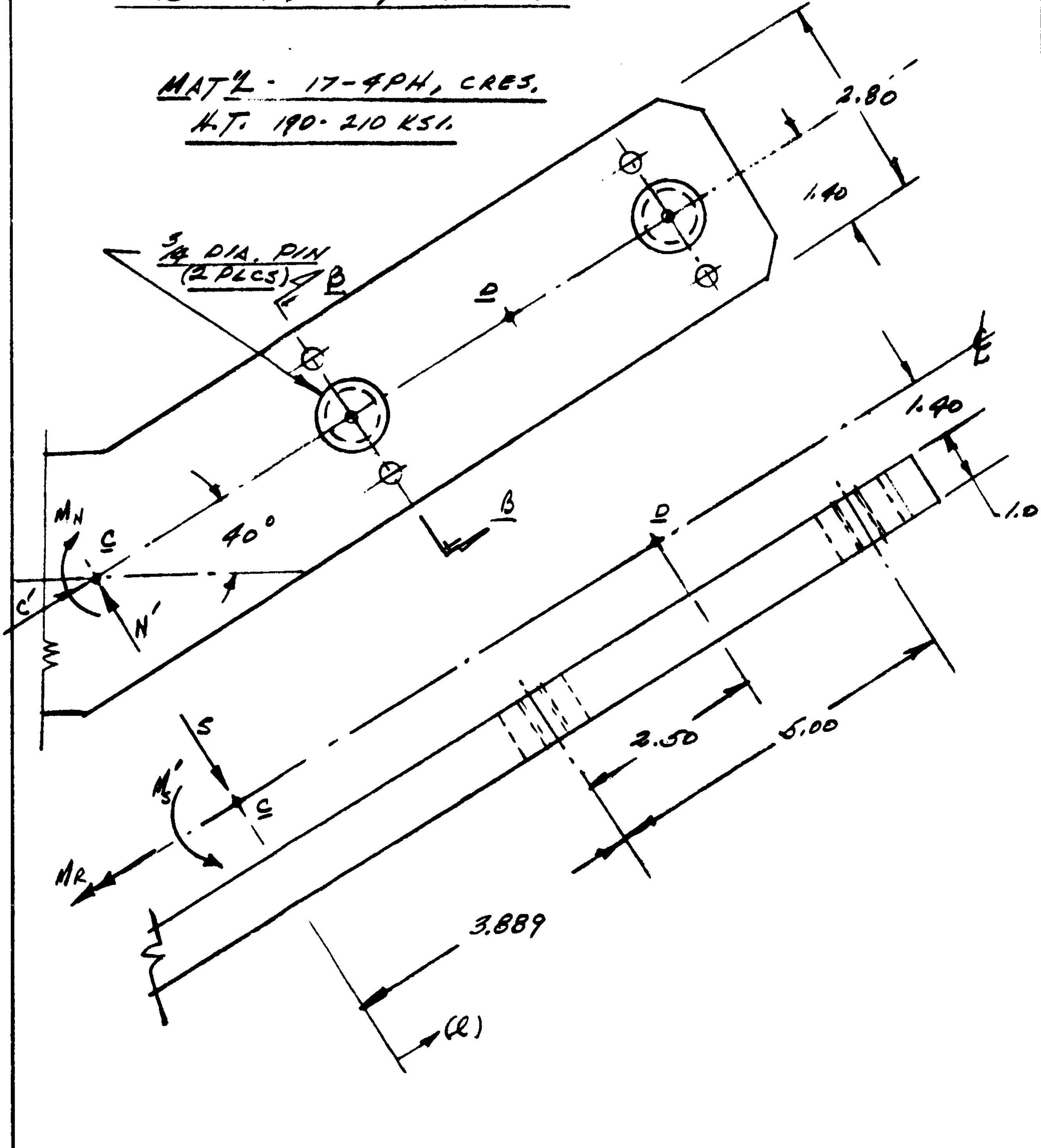
-2 SUPPORT ARM.

MAT'L - 17-4PH, CRES.
H.T. 190-210 KSI.



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-2 SUPPORT ARM (CONT.)

FOR STARTING CONDITION $\alpha = 40°$ IS CRITICAL (REF. PG. 17)

$M_{N_c} = 369(16.84+.024) = \underline{6223 \text{ IN-LB}}$

$M_{S_c} = 444(16.864) = \underline{7488 \text{ IN-LB.}}$

$N_c' = 369(\cos 40°) - 116(\sin 40°)$

$= 369(.76604) - 116(.64279)$

$= 282.7 - 75.1 = \underline{207.6 \text{ LB.}}$

$C_c' = 116(.76604) + 369(.64779)$

$= 88.9 + 239.0 = \underline{327.9 \text{ LB.}}$

$S_c = \underline{444 \text{ LB.}}$

$M_R = M_{S_c}(\sin 40°)$

$= 7488(.64279) = \underline{4813. \text{ IN-LB}}$

$M_S' = M_{S_c}(\cos 40°) + S(\ell)$

$= 444[(16.864)(.76604) + (\ell)]$

$= \underline{[5735.8 + 444(\ell)] \text{ IN-LB.}}$

7121-01087

-2 SUPPORT ARM (CONT.)

RUNNING CONDITION ($\alpha = 50°$)

$M_{N_C} = 910(16.84 - .13) = \underline{15,200 \text{ IN-LB}}$

$N' = 910(.76604) - 730(.64779)$

$= \underline{225 \text{ LB.}}$

$C' = 730(.76604) + 910(.64779)$

$= \underline{1150 \text{ LB.}}$

SECTION B-B - BENDING -

$M_{N(B-B)} = M_{N_C} + N'(3.889)$

$= 6223 + \underline{207.6}(3.889)$

$= \underline{7030 \text{ IN-LB}}$ (START.)

$M_{R(B-B)} = M_{R_C}$

$= \underline{4813 \text{ IN-LB}}$ (START.)

$M_{S'(B-B)} = 5735.8 + 444(3.889)$

$= \underline{7463 \text{ IN-LB}}$ (START)

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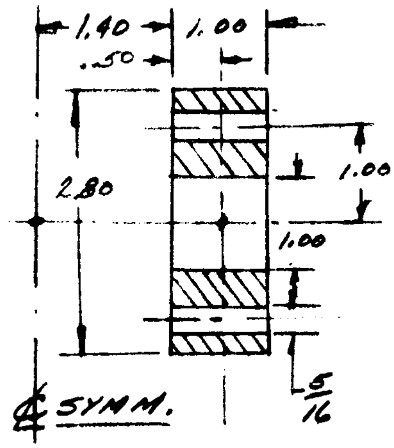
-2 SUPPORT ARM. (CONT.)

SECTION B-B (CONT.)

$$P_{(BB)/2} = \frac{C'}{2} + \frac{M\,S'_{(B-B)}}{3.80}$$

$$= \frac{327.9}{2} + \frac{7463}{3.80}$$

$$= \underline{2,128 \text{ LB.}} \text{ (START)}$$



½ SECT. B-B.
(REF. PG. 25)

$$M_{(BB)/2} = \frac{M_{N(BB)}}{2} + \frac{M_{R(B-B)}(3.889)}{3.80}$$

$$= \frac{7030}{2} + \frac{4813\,(3.889)}{3.80}$$

$$= \underline{8440 \text{ IN-LB}} \text{ (START)}$$

$$P_{(B-B)/2} = \frac{1150}{2} = \underline{575 \text{ LB}} \text{ (RUN)}$$

$$M_{(B-B)/2} = \frac{M_{N_C}}{2} + \frac{N'(3.889)}{2}$$

$$= \frac{15,200}{2} + \frac{225(3.889)}{2}$$

$$= \underline{8,040 \text{ IN-LB}} \text{ (RUN)}$$

7121-01087

-2 SUPPORT ARM (CONT.)

SECTION B-B (CONT.)

$$I_{BX} = \frac{b(D^3 - d^3)}{12} - 2[b(5/16)]$$

$$= \frac{1.00(2.80^3 - 1.00^3)}{12} - 2(.3125)(1.00)$$

$$= 1.746 - .6250 = \underline{1.121 \text{ IN}^4}$$

$$\bar{A}_{BB/2} = 1.00(2.80 - 1.00 - .625)$$

$$= \underline{1.175 \text{ IN}^2}$$

$$f_{b_{S_1}} = \frac{Mc}{I} + \frac{P}{A} = \frac{8440(1.40)}{1.121} + \frac{2128}{1.175}$$

$$= \underline{12,350 \text{ PSI}} \text{ (START)}$$

$$f_{b_{R_1}} = \frac{8040(1.40)}{1.121} + \frac{575}{1.175} = \underline{10,530 \text{ PSI}} \text{ (RUN)}$$

STARTING LOAD MOST CRITICAL

$$M.S. = \frac{190}{5(12.35)} - 1 = \underline{\underline{2.07}}$$

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-2 SUPPORT ARM (CONT.)

3/4 IN. DIA. PINS.

$$M_{N_D} = M_{N_C} + N'(3.889 + 2.50)$$

$$= 6223 + \underline{207.6}(6.389)$$

$$= \underline{7549 \text{ IN-LB.}} \text{ (START)}$$

$$M_{S'_D} = 5735.8 + \underline{444}(6.389)$$

$$= \underline{8573 \text{ IN-LB.}} \text{ (START)}$$

$$M_{R_D} = M_{RC}$$

$$= \underline{4813 \text{ IN-LB.}} \text{ (START)}$$

$$M_{N_D} = 15200 + \underline{225}(6.389)$$

$$= \underline{16,638 \text{ IN-LB.}} \text{ (RUN)}$$

$$P_{(PIN)_{S_1}} = \left\{ \left[\frac{M_{N_D}}{2(5.0)} + \frac{N_C'}{2(2)} + \frac{M_{R_D}}{2(2.80)} \right]^2 + \left[\frac{C_C'}{4} + \frac{M_{S_D}'}{2(2.80)} \right] \right\}^{\frac{1}{2}}$$

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-2 SUPPORT ARM (CONT.)

3/4 IN. DIA. PINS (CONT.)

$$P_{(PIN)_{S_1}} = \left\{\left[\frac{7549}{10.0} + \frac{207.6}{4.0} + \frac{4813}{5.60}\right]^2 + \left[\frac{327.9}{4.0} + \frac{8573}{5.60}\right]^2\right\}^{\frac{1}{2}}$$

$$= \left[(1666)^2 + (1613)^2\right]^{\frac{1}{2}}$$

$$= \left[5,377,325\right]^{\frac{1}{2}}$$

$$= \underline{2319 \text{ LB}} \text{ (START)}$$

$$P_{(PIN)_{R_1}} = \frac{M_{NO}}{10.0} + \frac{V_C'}{4}$$

$$= \frac{16,636}{10.0} + \frac{225}{4.0}$$

$$= \underline{1720 \text{ LB.}} \text{ (RUN)}$$

STARTING LOAD MOST CRITICAL -

SHEAR -

$$A_S = (.75)^2(.7854) = \underline{.442 \text{ IN}^2}$$

$$f_S = \frac{P}{A} = \frac{2319}{.442} = \underline{5247 \text{ PSI}}$$

$$M.S. = \frac{125}{5(5.25)} - 1 = \underline{3.76}$$

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-2 SUPPORT ARM - (CONT.)

5/16 A.H.C. SCREWS ADJACENT TO 3/4 PINS.

$$P_t = M_{S'_D} / 5.00(2) \quad \text{(CONSERVATIVE)}$$

$$= 8573/10.0 = \underline{857.3\ LB.}$$

$$M.S. = \frac{9264}{5(857)} - 1 = \underline{\underline{1.16}}$$

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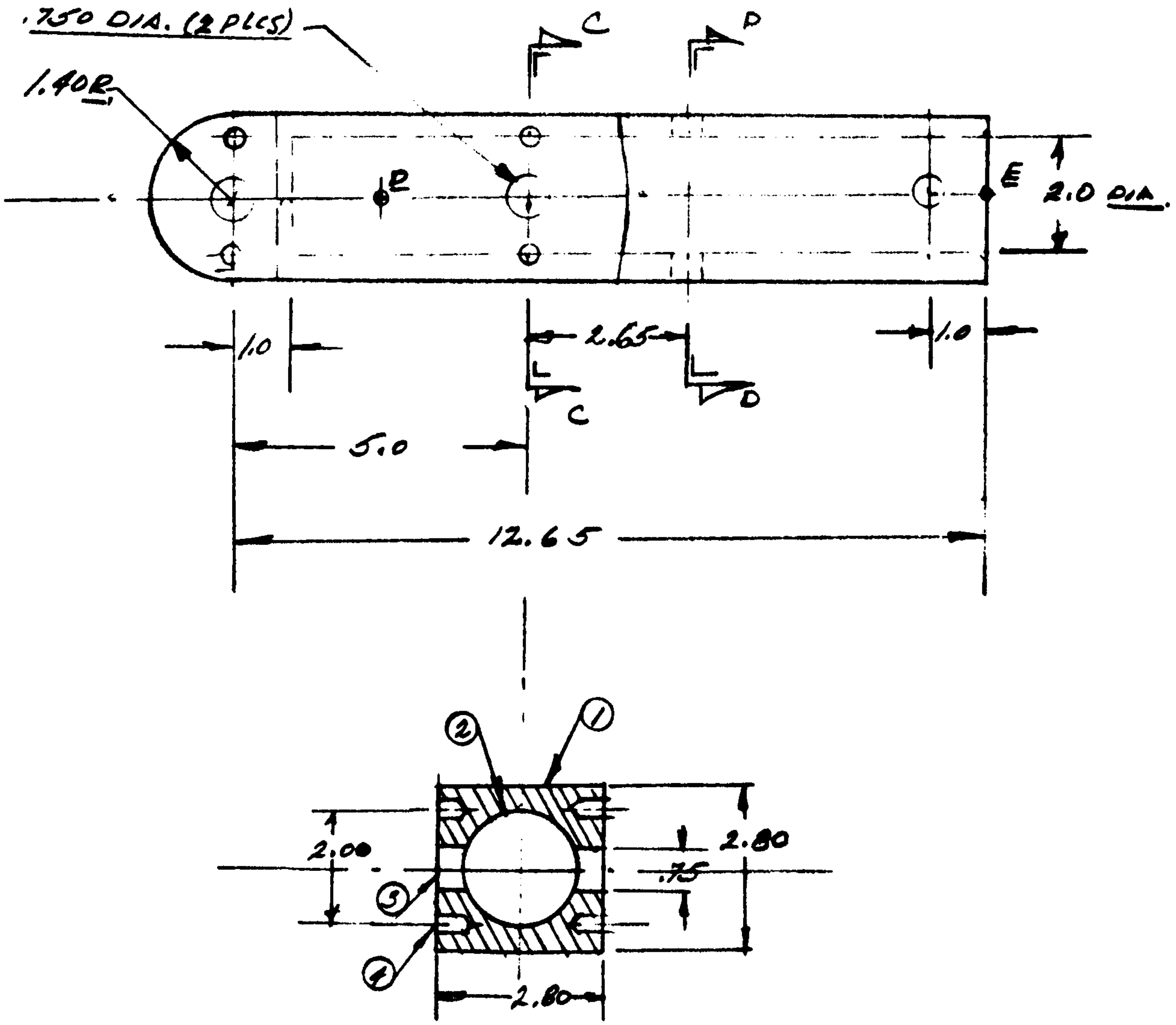
- 6 STING ADAPTOR

MAT'L, 17-4PH CRES
H.T. 190-210 KSI.



SECT. C~C

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-6 STING ADAPTOR (CONT.)

SECTION C~C

SECTION PROPERTIES -

ITEM		A	Y	Ay^2	X	Ax^2	I_{ox}	I_{oy}
1	+(1)	+7.8400	—	—	—	—	5.1221	5.1221
2	-(1)	-3.1416	—	—	—	—	-.7856	-.7856
3	-(2)	-.6000	—	—	±1.20	.8640	-.0141	-.0040
4	-(4)	-.7812	1.00	.7812	1.087	.9239	—	—
		3.3172		-.7812		-1.7879	4.3224	4.3325

$A = 3.3172\ IN^2$

$I_{xx} = 4.3224 - .7812 = 3.5412\ IN^4$

$I_{yy} = 4.3325 - 1.7879 = 2.5446\ IN^4$

LOADS AT SECTION C~C

$M_{N(C)} = M_{N_D} + N_D'(2.50)$

$= 7549 + 207.6(2.50) = 8068$ IN-LB (5,)

$M'_{S(C)} = M'_{S_D} + S_D(2.50)$

$= 8573 + 444(2.50) = 9683$ IN-LB. (5,)

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- 6 STING ADAPTOR (CONT.)

SECTION C~C (CONT.)

$$M_{N_c} = 16{,}638 + \underline{225}(2.50) = \underline{17{,}200 \text{ IN-LB } (R_1)}$$

BENDING -

$$f_b = \Sigma \frac{Mc}{I} + \frac{P}{A}$$

$$= \frac{8068(1.40)}{3.5412} + \frac{9683(1.40)}{2.5496} + \frac{327.9}{3.3172}$$

$$= \underline{8{,}616 \text{ PSI}} \quad (\text{START})$$

$$= \frac{17200(1.40)}{3.5412} + \frac{1150}{3.3172}$$

$$= \underline{7150 \text{ PSI}} \quad (\text{RUN})$$

$$M.S. = \frac{190}{5(8.616)} - 1 = \underline{\underline{3.41}}$$

7121-01087

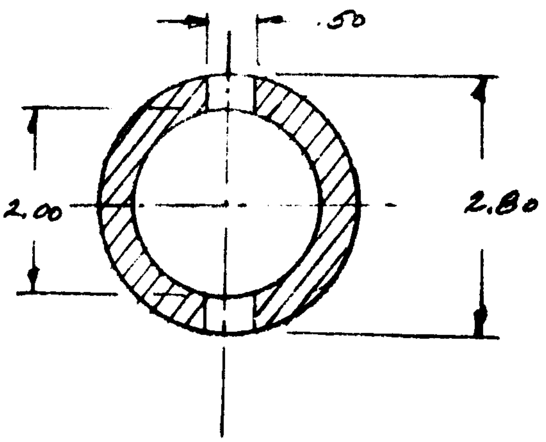
-6 STING ADAPTOR (CONT.)

SECTION D-D-

$$I_{xx} = .0491(2.80^4 - 2.00^4) - 2(.50)(.40)(1.20^2)$$

$$= 2.2324 - .5760$$

$$= \underline{1.6564 \text{ IN}^4}$$



$$A_{D\text{-}D} = .7854(2.80^2 - 2.00^2) - 2(.50)(.40)$$

$$= \underline{2.616 \text{ IN}^2}$$

SECT. D-D.

$$M_{N(D\text{-}D)_S} = 8068 + 207.6(2.65) = 8618 \text{ IN-LB.}$$

$$M_{S'(D\text{-}D)_S} = 9683 + 444(2.65) = 10{,}860 \text{ IN-LB.}$$

$$M_{(D\text{-}D)_S} = \left[(8618)^2 + (10{,}860)^2\right]^{\frac{1}{2}} = \underline{13{,}864 \text{ IN-LB.}}$$

$$M_{N(D\text{-}D)_R} = 17{,}200 + 225(2.65) = \underline{17{,}796 \text{ IN-LB}}$$

7121- 01087

-6 STING ADAPTOR (CONT.)

SECTION D~D (CONT.)

$$f_b = \frac{MC}{I} + \frac{P}{A} = \frac{17{,}796(1.40)}{1.6564} + \frac{1150}{2.616}$$

$$= \underline{15{,}990 \text{ PSI.}}$$

$$F_B = \underline{190 \text{ KSI.}} \quad (\text{REF. } 1)$$

$$M.S. = \frac{190}{5(15.99)} - 1 = \underline{\underline{1.45}}$$

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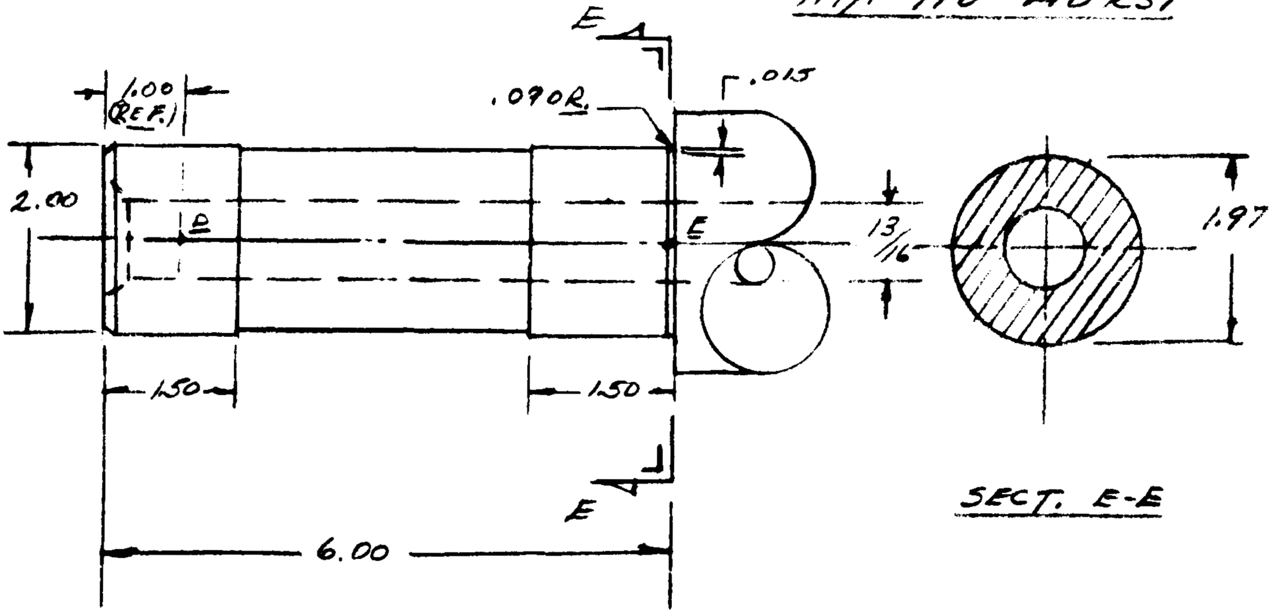
AMES STING-

SECT. E-E.

MAT'L - 17-4PH
H.T. 190-210 KSI



$$I_{EE} = (1.97^4 - .813^4)(.0491) = \underline{.7181\ IN^4}$$

$$M_{N_R} = M_{DD} + N_R'(5.00)$$

$$= 17{,}796 + 225(5.00) = \underline{18{,}921\ IN.-LB.}$$

NEGLECTING CHORD COMP. (C_D = 1150 LB.)

BENDING-

$$f_b = \frac{MC}{I} = \frac{18920(.985)}{.7181} = \underline{\underline{25{,}940\ PSI}}$$

$$M.S. = \frac{190}{5(25.94)} - 1 = \underline{\underline{.46}}$$

APPENDIX C

MODIFICATION TO UPDATE THE FS-2 MODEL

ABSTRACT

This Appendix presents a structural analysis of the components of the FS-2 Apollo Force Model that have been modified or added to update the model to the latest configuration. Testing will be conducted in the Ames Unitary Plan Wind Tunnel.

The analysis of new or modified components is presented in full. Components that are not modified are analyzed by a comparative analysis for a 90-degree α at 540 q.

NT 63-3

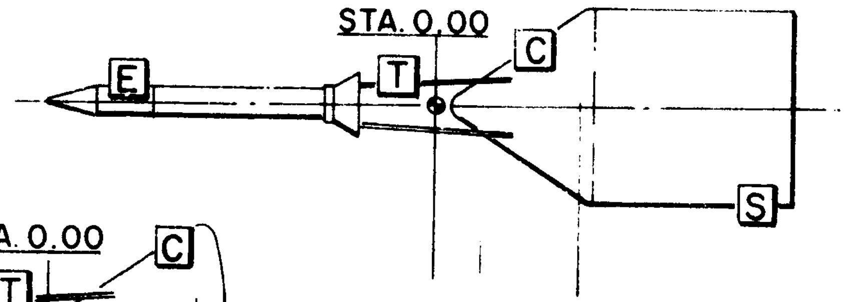
LOADS, APOLLO — WIND TUNNEL MODEL

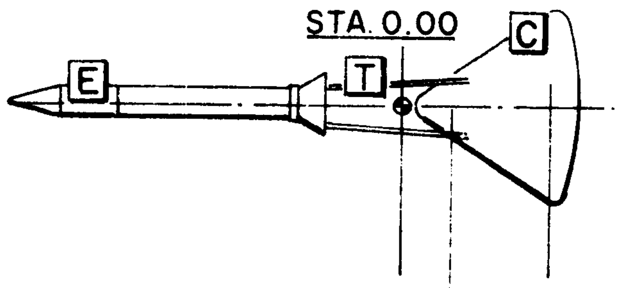
MODEL FS-2
SCALE 0.105
TUNNEL AMES 9'x7'
TEMP.
MACH NO. 1.55
q = 540 PSF
α = 75°
STEADY STATE LOADS — ☒
TRANSIENT LOADS — ☐

REQUIRED SAFETY FACTORS:—
5 ON ULTIMATE
3 ON YIELD

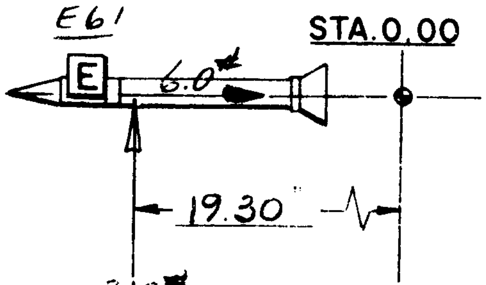
NOTES:—
(1)-LOADS GIVEN IN POUNDS. DIMS. IN INCHES, (MODEL SCALE).
(2)-

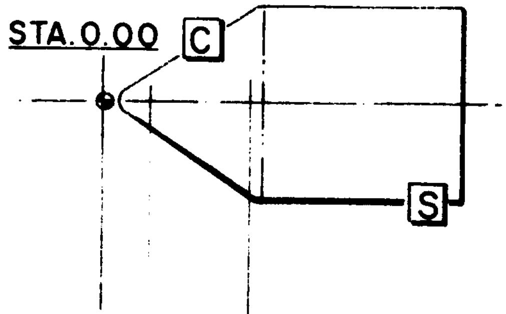
TOTAL CONFIGURATION LOADS:

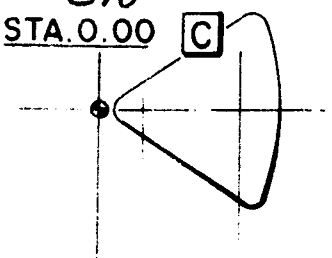


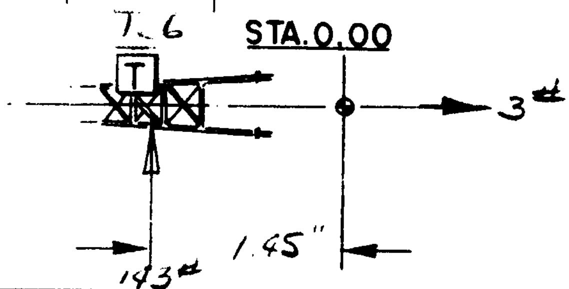


LOADS ON COMPONENTS:









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	SHEET 1 OF 2	

REF DWG # ...

ENCLOSURE (1)

PAGE 1

WTL-63-3

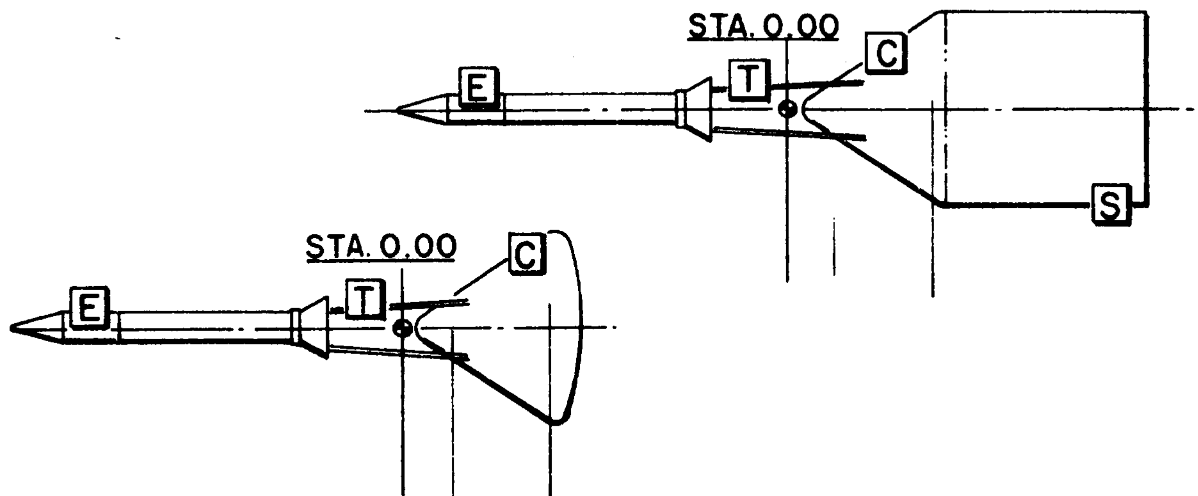
LOADS, APOLLO — WIND TUNNEL MODEL

MODEL FS-2
SCALE 0.105
TUNNEL AMES 9'x7'
TEMP.
MACH NO. 1.55
q = 540 PSF
α = 90°
STEADY STATE LOADS — ☒
TRANSIENT LOADS — ☐

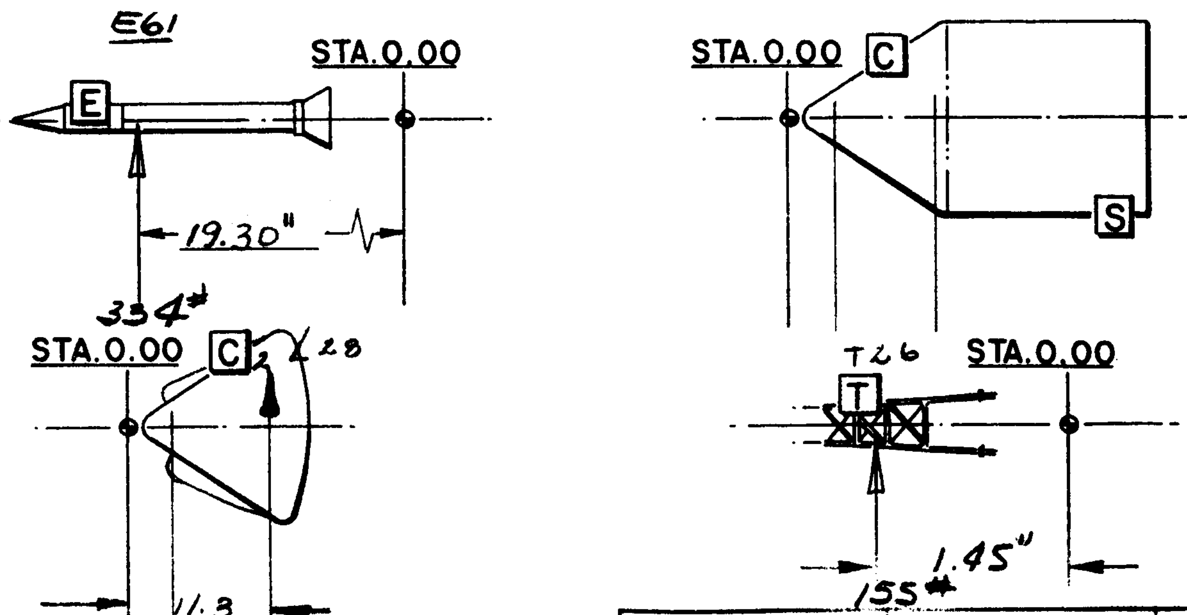
REQUIRED SAFETY FACTORS:—
5 ON ULTIMATE
3 ON YIELD

NOTES:—
(1)—LOADS GIVEN IN POUNDS. DIMS. IN INCHES, (MODEL SCALE).
(2)—

TOTAL CONFIGURATION LOADS:



LOADS ON COMPONENTS:



REF. DWG. # 7121-01091

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ENCLOSURE (1)

PQ63-1

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7121-01091

ROCKET BODY (7121-01089-3 REF.)

LOADS –

$L/d = (37.472 - 14.49)/2.73 = 8.42$

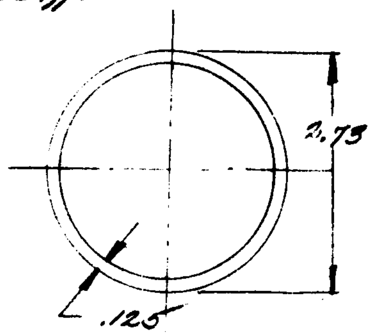
$C_d = .90$ (REF. ESHBACH Pg 7-103)

$p = 540(.90)(2.73)/144 = \underline{9.21 \text{ LB/IN.}}$

BENDING – SECTION AT X_L 19.964

$M = pL/2 = 9.21(39.718 - 19.964)/2$

$= \underline{91.0 \text{ IN-LB.}}$



SECTION

$S = .0983(D^4 - d^4)/D$

$= \underline{.2779 \text{ IN}^3}$

$f_b = M/S = 91.0/.2779$

$= \underline{327.4 \text{ PSI}}$

M.S. = HIGH.

7121-01091

ROCKET BASE (-3 SKIRT)

TOWER ATTACHMENT TO ROCKET SKIRT

(STATION X_L 12.60)

$M = 334\ (19.30 + 6.067 - 12.60)$

$= 334\ (12.767) = \underline{4264 \text{ IN-LB.}}$

LOAD PER LEG $= M/2(3.787)$

$= 4264 / 7.574 = \underline{563 \text{ LB.}}$

WELD SHEAR - ASSUME 1/8 FILLET.

$A_S = .70(2)(.125)(.707) = .1237 \text{ IN}^2$

$f_{s_D} = P/A_S = 563/.1237$

$= \underline{4551 \text{ PSI}}$ DIRECT SHEAR

ECCENTRIC LOAD SHEAR

$M_e = 563(.1875) = 105.6 \text{ IN-LB}$

$S = 2(.125)(.707)(.70)^2/6$

$= .0138 \text{ IN}^3$

$f_{s_e} = 105.6/.0138 = \underline{7650 \text{ PSI}}$

$f_s = \left[(4551)^2 + (7650)^2\right]^{\frac{1}{2}} = \underline{8,900 \text{ PSI}}$

$M.S. = \dfrac{125}{5(8,900)} - 1 = \underline{1.80}$

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TOWER LEGS (-2 TOWER)

LEG LOAD -

$$M_{(XLE.06?)} = 334(19.30) + 155(1.45)$$
$$= \underline{6670.9 \text{ IN-LB.}}$$

$$P_L = M/2d$$

$$d = 4.910 - [(4.910 - 3.787)5.27/11.60]$$
$$= 4.910 - .469 = 4.441 \text{ IN.}$$

$$P_L = 6671/8.88 = \underline{751 \text{ LB./LEG.}}$$

COMPRESSION -

$$L = (12.18 - 6.27)/.99656^{(a)} = \underline{5.93 \text{ IN.}}$$

$$P_{CRIT.} = 4\pi EI/L^2$$
$$= 4(3.1416)(28.5\times10^6)(.0491)(.375)^4/5.93^2$$
$$= .500(.0527) = .02636\times10^6 \text{ LB.}$$
$$= \underline{26360 \text{ LB.}}$$

NOT CRITICAL.

TOWER LOWER BAY LEGS NOT CRITICAL

3,

a. DIRECTION COSINE.

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TOWER BRACING (- 2 TOWER)

ASSUME MEMBERS ACT IN TENSION ONLY

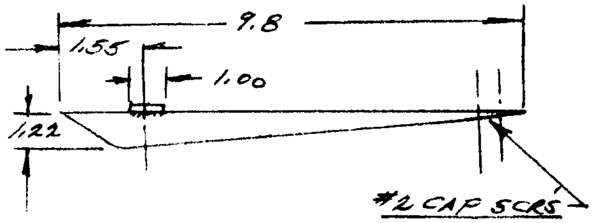
NORMAL LOAD = 334 + 155 = 489 LB.

$P_t = 489/2(.53189)^{(a)} = \underline{459\ LB.}$

$f_t = P/A = 459/(.7854)(.25)^2 = \underline{9,350\ PSI}$

$M.S. = \frac{190}{5(9.35)} - 1 = \underline{3.06}$

COMMAND MODULE STRAKES -



AREA -

$A = 9.8(1.22)/2$

$= \underline{5.978\ IN^2}$

LOAD - ASSUME C_d OF 2.0 -

$P = 540(5.978)(2.0)/144 = \underline{44.8\ LB.}$

M AT BASE $= 44.8(1.22)/3 = \underline{18.2\ IN\text{-}LB.}$

WELDED LUG -

ASSUME LUG TAKES 70% OF LOAD.

a. SMALLEST DIRECTION COSINE FOR NORMAL LOADING.

7121-01091

COMMAND MODULE -

STRAKES - 17-4PH (NOT H.T.)

$M = .70(18.2) = \underline{12.74}$ IN-LB

$A_S = 1.00(.125)(.707) = \underline{.0884 \text{ IN}^2}$

$P = M/.158 = 12.74/.158 = \underline{80.6 \text{ LB.}}$

$f_s = P/A = 80.6/.088 = \underline{912 \text{ PSI}}$

$F_S = \underline{75 \text{ KSI}}$

$M.S. = \dfrac{75}{5(.915)} - 1 = \underline{\underline{\text{HIGH}}}$

TAB BENDING -

$M = 12.74/2 = 6.37$ IN LB.

$S = bd^2/6 = 1.00(.15)^2/6 = .00375 \text{ IN}^3$

$f_b = 6.37/.00375 = \underline{\underline{1,670 \text{ PSI}}}$

TAB SCREWS - #

$t = M/d = 12.74/.70 = \underline{\underline{18.2 \text{ LB.}}}$

$T_{\#2 \text{ CAP}} = \underline{\underline{624 \text{ LB}}}$

NOT CRITICAL

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V16-010911-

COMMAND MODULE

STRAKES

AFT SCREWS -

$M = .30(18.2) = 5.46$ IN-LB

$t = M/d = 5.46/2(.070)$

$= \underline{39.0}$ LB. TENSION.

$M.S. = \frac{624}{5(39.0)} - 1 = \underline{2.20}$

7121-01091

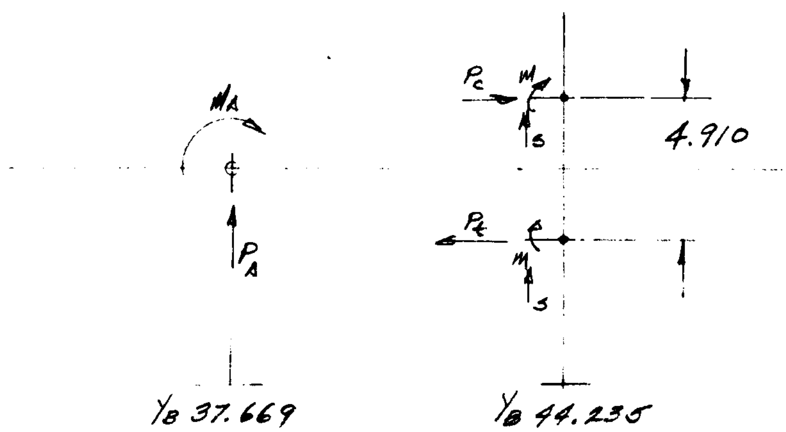
MODEL MOUNTING SYSTEM -

ROCKET & TOWER LOADS ABOUT APEX. -

$P_A = 334^{(a)} + 155^{(a)} = \underline{489}$ LB.

$M_A = 334(19.30)^{(a)} + 155(1.45)^{(a)} = \underline{6671}$ IN-LB.

COMPARATIVE LOADS FOR TOWER MOUNT
(REF. APP. A. PG. A-17) (7121-01078)



$P_c = P_t = [M_A + P_A(44.235 - 37.669)]/4.910(2)$

$= [6671 + 489(6.566)]/9.82$

$= \underline{1006 \text{ LB.}}$

THIS IS A 20% REDUCTION IN LOAD
(REF. PG. A-17, APP. A.)

a. REF. PG. C-4

7121-01091
7121-01078

MODEL MOUNTING SYSTEM. -

COMPARATIVE LOADS FOR TOWER MOUNT -

$S = 489/4 = \underline{\underline{122.3 \text{ LB}}}$

$M = 122.3(.6)(1.00) = \underline{\underline{73.4 \text{ IN-LB}}}$

P_t, S, & M ARE LOWER THAN PREVIOUS LOADS THAT THE SAME SIZE DETAIL WAS ANALYZED FOR. (REF PG'S A-17 THRU A-20, APP. A.).

-5 TOWER MOUNT IS NOT MORE CRITICAL THAN BEFORE AS THE ABOVE LOADS ARE RESISTED BY THE SAME -5 BLOCK AS BEFORE. (REF. PG. A-21, APP. A.)

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BALANCE & STING CHECK LOADS -

FORCES & MOMENTS ABOUT CENTER OF ROTATION FOR COMPLETE MODEL:

C.R. IS AT Y_B 46.861 -

$N = P_{C.R.} = 334 + 155 + 460 = \underline{\underline{949 \text{ LB.}}}$

$P.M. = M_{C.R.} = 334(19.30) + 155(1.45) - 460(11.3)$

$+ 949(46.861 - 37.669)$

$= \underline{\underline{10,196 \text{ IN-LB.}}}$

THESE LOADS ARE LESS THAN 90 α STEADY STATE AT THE SAME C.R. FOR PREVIOUS TESTS. (REF. APP. A. PG. A-27.)